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Essays on Collective Bargaining, Wage Inequality and Firm Dynamics

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Doctor of Philosophy



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Declaration of Own Work

I declare that this thesis was written and composed by myself and is the result of my own work unless clearly stated and referenced. This thesis has not been submitted for any other degrees or professional qualifications.

The work presented in Chapter 2 is based on my work with my supervisors, Cristina Tealdi and José V. Rodríguez Mora who agreed that the essay can appear within this thesis, and that it represents a substantial contribution on my part. In particular, I carried out all of the empirical work, coding, analysis of the results and writing of the paper. Prof Tealdi and Prof Mora provided guidance and direction for the project and were instrumental in securing access to the data.

Juraj Briskar

*To Rachel and my parents, Juraj and Jarmila
Without you this thesis would not have been possible*

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Abstract of Thesis

In this thesis I study collective bargaining, wage inequality, firm dynamics and the ways in which they interact. In the first chapter I investigate the extent to which wages vary across different industries after controlling for detailed worker and job characteristics and how this is related to the wage setting institutions of a given country. In the second chapter I study the drivers of the growth in earnings and wage inequality in Italy between 1985 and 2018 and compare them to the USA. In the third chapter I build a large-firm search model with heterogeneous firms and endogenous firm entry in order to compare the aggregate implications of firm-level and sector-level wage setting.

Chapter 1: Informal Coordination of Wage Bargaining and the Size of Sector Wage Premiums I use the Eurostat’s Structure of Earnings Survey which is a unique data set containing microdata harmonised across European countries in order to investigate the relationship between wage setting institutions and wage dispersion. First, I find that in countries where the main level for wage bargaining is the sector, the dispersion of wages across sectors after controlling for detailed worker and job characteristics is substantially smaller than in countries where wage bargaining occurs predominantly at the firm level. This is surprising given that sector-level bargaining implies equalising wages only for each worker type within industries. The result points towards strong informal coordination of wages across sectors achieved via pattern bargaining. Second, I find that the overall wage dispersion is larger in the countries with firm-level wage setting. As a result, the relative share of the overall wage inequality that can be attributed to the sector that a worker is

employed in is not generally larger in the countries with firm-level wage setting. Third, I find that in countries with sector-level wage setting observable worker characteristics explain a larger fraction of the overall wage variance. This is likely because wages are not individually bargained, but are based on a collectively bargained formula that includes characteristics such as worker occupation, education, years of experience and tenure.

Chapter 2: It's the Sectors, not the Firms: Accounting for Earnings and Wage Inequality Trends in Italy 1985-2018 Using administrative data for the entire universe of private-sector employment in Italy for the period 1985-2018 we investigate the drivers of the growth in earnings and wage inequality and compare them with other countries, in particular the USA. First, we find that the majority of the increase in earnings inequality in Italy (62%) is due to an increase in the variance of average earnings between firms and only about 38% is due to increased variance within firms. This is very similar to the results found for the US (Song et al. (2019)). Second, we decompose the between-firm variance into the between-sector variance and the between-firms-within-sector variance. Whereas in the US, the contribution of the between-sector variance to the overall growth in earnings dispersion is minimal and the majority of the growth of inequality is a between-firm-within-sector phenomenon, in Italy the rising between-sector variance explains approx. 42% of the overall increase in earnings dispersion, with the between-firm-within-sector component playing only a small role. The most likely explanation for the different patterns of rising earnings inequality between Italy and the USA seems to be differences in wage-setting institutions. Wage bargaining in the US is at the firm level whereas in Italy over 90% of workers are covered by sector-level collective agreements that specify wage floors for each occupation. This does not necessarily mean that sector wage premiums became larger in Italy. It is much more likely that the sector-level negotiators simply allowed increases in the relative demand for high skilled workers driven by technological changes to be reflected in the minimum wages for different occupations. This in combination with the fact that occupational composition of the workforce differs hugely between the narrowly defined industries, but arguably much

less within them can potentially explain why the growth of earnings (and wage) dispersion between sectors accounted for such a large share of the overall growth of inequality in Italy. Finally, we find that the pattern found in the USA, the UK and Brazil, that changes in the dispersion of average earnings between firms within the same narrowly defined industries explain the majority of the changes in earnings dispersion, is not universal.

Chapter 3: The Aggregate Implications of Sector-Level vs Firm-Level Wage Setting in a Frictional Labour Market I compare a setting where a firm negotiates wages with each worker separately with a two-tier collective bargaining framework. In the latter case a sector-wide union and an employer organisation first bargain over the tariff wage that applies to all the homogeneous workers and then additional wage premiums are bargained collectively at firm-level. The model can vary the extent of centralisation of wage bargaining by adjusting the ability of workers to organise industrial actions at firm-level. The modelling framework is a search model with multi-worker firms that are heterogeneous in productivity. As a result of fixed costs of production there is a threshold firm productivity level and thus a firm-selection mechanism. Under firm-level bargaining (either individual or collective) there is wage dispersion across firms driven by rent sharing and the wage is an increasing function of the firm's output per worker. Because of convex hiring costs firms only gradually grow towards their target size. Given that firm productivity is constant over the life of the firm and there are decreasing returns to scale, wage is declining in firm age. Firms with higher permanent productivity face higher wages along their entire growth path. My main finding is that reducing wage dispersion across firms while keeping average wage constant leads to a higher total value added. I provide two novel arguments in favour of sector-level bargaining. Firstly, centralised wage setting can reduce the young firm wage premium and thus encourage more firm entry. Secondly, it can weaken the link between firm size and wages and thus reduce the inefficiencies associated with the over-employment effect which has been identified by the existing literature.

Lay Summary

In this thesis I investigate the economic implications of trade unions, the possible drivers of the growth in wage inequality, the mechanisms affecting incentives for firm creation and firm closures and the interactions between these three broad areas. In the first chapter I investigate the extent to which wages for workers with the same education, years of experience and tenure performing the same occupations vary across different industries and how this is related to the predominant way in which wages are set in a given country. Wages can be negotiated individually between each worker and the firm; between a firm-level trade union and the firm or between a sector-level trade union representing all the employed workers in that industry and an organisation representing all the employers in that industry. In the second chapter I study the drivers of the growth in earnings and wage inequality in Italy between 1985 and 2018 and compare them to the USA. In the third chapter I build a model of the labour market in order to compare the implications of firm-level and sector-level wage setting for the quantity of goods produced, the level of employment and other economic outcomes.

In the first chapter I use the Eurostat's Structure of Earnings Survey which is a unique data set containing information on worker and firm characteristics that is harmonised and thus comparable across European countries in order to investigate the relationship between wage setting institutions (the way that wages are set) and wage inequality. First, I find that in countries where the main level for wage bargaining is the sector, wages for workers with the same characteristics performing the same occupation vary less across industries than in

countries where wage bargaining occurs predominantly at the firm level. This is a surprising result. Given that under sector-level collective wage bargaining certain standard wage rates are set for each occupation and these tariff wages then apply to all the firms in the industry we would expect that wages are equalised for each type of worker within industries, but it is not obvious that wages should be equalised across industries. I find that the European countries where wages for each worker type are most similar across industries tend to have strong informal coordination of wages where one sector agrees on wages first and the resulting pay rise becomes a benchmark for the other sectors. Second, I find that the share of the wage inequality that can be explained by the sector that a worker is employed in is not systematically different between countries with sector-level and firm-level wage bargaining. While countries where wages are mostly set at firm level have larger sector wage premiums, their overall wage inequality is also larger because they have more inequality coming from other sources as well. Third, I find that in countries where wages are mostly set by collective bargaining at the level of industry, observable worker characteristics can explain a greater share of the total wage inequality. This is likely because wages are not individually bargained, but are based on a collectively bargained formula that includes characteristics such as worker occupation, education, years of experience and tenure.

In the second chapter I use social security data that covers all private-sector employment in Italy for the period 1985-2018 in order to investigate the drivers of the growth in earnings and wage inequality and compare them with other countries, in particular the USA. First, we find that the majority of the increase in earnings inequality in Italy (62%) is due to an expansion of the differences in average earnings across firms and only about 38% is due to increased inequality within firms. This is very similar to the results found for the US (Song et al. (2019)). Second, we decompose the pay inequality between firms into two components, the differences in average earnings across sectors and the differences in average earnings across firms within the same sector. Whereas in the US, the contribution of the between-sector inequality to the overall growth in earnings inequality is minimal and the majority of

the growth of inequality is a between-firm-within-sector phenomenon, in Italy the expanding differences in average earnings across sectors explain approx. 42% of the overall increase in earnings inequality, with the between-firm-within-sector component playing only a small role. The most likely explanation for the different patterns of rising earnings inequality between Italy and the USA seem to be differences in the way wages are set. Wage bargaining in the US is at the firm level whereas in Italy over 90% of workers are covered by sector-level collective agreements that specify wage floors for each occupation. This does not necessarily mean that some sectors were increasingly paying higher wages than other sectors for workers with the same characteristics performing the same occupations. It is much more likely that the sector-level negotiators simply allowed increases in the productivity of high skilled workers relative to low skilled workers driven by technological changes to be reflected in the minimum wages for different occupations. This in combination with the fact that occupational composition of the workforce differs hugely between the narrowly defined industries, but arguably much less within them can potentially explain why the growth of earnings (and wage) inequality between sectors accounted for such a large share of the overall growth of inequality in Italy. Finally, we find that the pattern found in the USA, the UK and Brazil, that changes in the dispersion of average earnings between firms within the same narrowly defined industries explain the majority of the changes in earnings inequality, is not universal.

In the third chapter I build a model of the labour market in order to investigate the economic implications of different degrees of centralisation of wage bargaining, i.e. whether wages are negotiated between each firm and its workforce (the decentralised case) or wages are negotiated by a sector-wide trade union representing all the employees in the industry and an employer organisation representing all the firms in the industry (the centralised case). In particular, I compare a setting where a firm negotiates wages with each worker separately with a two-tier collective bargaining framework. In the latter case a sector-wide union and an employer organisation first bargain over the tariff wage that applies to all the homogeneous workers and then additional wage premiums are bargained collectively at firm-level. The

model can vary the extent of centralisation of wage bargaining by adjusting the ability of workers to organise industrial actions at firm-level. In my model matching of unemployed workers to empty vacancies is a costly and time-consuming process. When a firm is created the owner learns the firm's productivity which is fixed over the life of the firm. There is a certain minimum level of productivity that firms need to have in order to be profitable and choose to produce in the industry. Firms only gradually grow towards their target size. As the number of workers a firm has increases, the amount that each worker produces declines. Under firm-level wage bargaining, the higher the amount of the good produced per worker at the firm, the higher the wage rate that the firm has to pay to its workforce. Therefore the wage declines as the firm grows larger. This encourages firms to grow larger than would otherwise be optimal. Additionally, because younger firms had less time to grow their workforce, the wage that they face is higher, there is a young firm wage premium. My main finding is that in the context of this model, reducing wage dispersion across firms while keeping average wage constant leads to a larger amount of the goods that can be consumed. I provide two novel arguments in favour of sector-level bargaining. Firstly, by making wages more similar across firms the centralised wage setting can reduce the young firm wage premium which encourages more firms to be created. Secondly, it can weaken the link between firm size and wages and thus reduce the inefficiencies associated with the over-employment effect which has been identified by the existing literature.

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Chapter 1

Informal Coordination of Wage Bargaining and the Size of Sector Wage Premiums

1.1 Introduction

In a competitive labour market all firms face the same price for labour of a given type. However, a long literature in labour economics has shown that some industries systematically pay substantially higher wages than other industries to workers with similar observable skills performing the same occupations (Dickens (1987), Krueger and Summers (1988)). The two main explanations are either differences in wage policies across sectors (some sectors paying wage premiums because of rent sharing), or sorting into sectors based on unobservable worker ability (Gibbons and Katz (1992)). These conditional inter-industry wage differentials are persistent across time, present in every country, but to varying degrees.

One country characteristic that has proven to be a good predictor of the dispersion of inter-industry wage differentials is centralisation of wage bargaining. Wage bargaining between representatives of unions and employers can take place at the level of the firm (the

most decentralised case), at the level of the industry, or at the level of the entire private sector. The main effect of centralisation is to equalise wages for each occupation across heterogeneous firms within the bargaining unit which is either a particular industry or the entire private sector (Barth, Moene, and Willumsen (2014)).

Zweimuller and Barth (1994), Teulings and Hartog (1998) and Kahn (1998) found that in 1980s the countries with the most centralised wage bargaining at the time, Sweden, Norway and Austria, had 3-4 times smaller differences in wages across industries conditional on observables than countries with the least centralised (firm-level) bargaining, the USA and Canada. Given that at that time Sweden, Norway and Austria had wage setting at the level of the entire private sector this is perhaps not a surprising result.

However, there has been a dramatic shift towards decentralisation of wage bargaining in Europe since 1980s. These days the main level at which wage bargaining takes place is either the sector or the firm. I investigate whether the negative relationship between the degree of centralisation of wage bargaining and the size of sector wage premiums still exists¹. Given that sector-level bargaining only implies equalizing wages for each worker type within the sector it is not immediately obvious that the relationship should still hold.

I use the Eurostat's Structure of Earnings Survey which is a unique data set in that it contains linked employee-employer data that is harmonised across the European countries. This enables me to run the same regression model across all the countries and obtain comparable estimates. I use the 2006, 2010 and 2014 issues of this cross-sectional establishment survey².

I regress log hourly wages on worker and job characteristics (education, age, gender,

¹I use sector and industry interchangeably in this chapter. When using terms industry or sector wage differentials I always mean conditional on worker and job characteristics.

²Gannon, Plasman, et al. (2007), Caju, Lamo, et al. (2010) and Magda et al. (2011) also use the Structure of Earnings Survey (either 1995 or 2002 issue) and estimate industry wage differentials for multiple countries. However, their focus is different from mine. Gannon, Plasman, et al. (2007) examine the interaction between the inter-industry wage differentials and the gender wage gap. Caju, Lamo, et al. (2010) correlate industry wage differentials with industry characteristics in order to understand the fundamental cause of industry wage differentials. Magda et al. (2011) focus on East-West comparison of the dispersion of industry wage differentials in Europe.

tenure, occupation, full time vs part time work, permanent vs temporary contract) and a set of dummy variables, one for each industry category. The OLS coefficients on these industry dummy variables, after some standard transformations³, become the inter-industry wage differentials. They tell us the wage premium that a sector pays relative to the economy-wide average conditional on worker and job characteristics. For each country-year pair I calculate a measure of dispersion of the inter-industry wage differentials following the standard approach in the literature.

I find that there is a very large variation in wages across sectors even after controlling for detailed worker and job characteristics and that the size of this dispersion varies significantly across the European countries. For example in 2014 the dispersion of inter-industry wage differentials was almost 3 times larger in Bulgaria than in Belgium and it was twice as large in Romania than in Finland.

My first major result is that countries with sector-level wage setting have substantially smaller dispersion of inter-industry wage differentials than countries with predominantly firm-level wage setting. I also find that countries that are ranked as having a larger degree of coordination of wage bargaining have smaller sector wage differentials⁴. Coordination measures the extent to which unions and employer organisations reflect wage increases in other sectors in their own negotiations (Ibsen (2016)). Hence it seems that sector-level wage bargaining enables more coordination of wage-setting across different parts of the economy. While there is no longer formal or enforced coordination of wage setting across industries (as was the case for a number of countries up to 1980s), there is often a certain degree of informal coordination. An example of this is the pattern bargaining system where wage bargaining takes place in one sector first, typically in the export-oriented manufacturing sector, and the resulting wage increase becomes the benchmark for negotiators in other sectors (Ibsen (2015)). Because of a widely shared concern about maintaining international

³Details in the Methodology section.

⁴The ranking comes from the Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts.

competitiveness the wage increase in the trend-setting tradable sector represents an upper bound on possible wage increases in the sheltered industries (Barth and Moene (2013)).

Interestingly, I find that the dispersion of industry wage differentials is much larger in the UK and in Central and Eastern Europe than in Western European countries. Hence I corroborate the finding of Magda et al. (2011)⁵. This sharp geographical divide can be explained by the difference in wage setting institutions. While wage bargaining in Western Europe is predominantly at the sector level, in Eastern Europe and the UK it is mainly at the firm level.

In addition to estimating industry wage differentials I also apply a regression-based decomposition of variance of the dependent variable proposed by Fields (2003). This way I can find what fraction of the variance of log hourly wages can be explained by each explanatory factor. This allows me to contrast the relative importance of sector that a worker is employed in for explaining wage dispersion in different countries.

My second major result is that there is no significant difference between countries with sector-level and firm-level wage setting in the relative share of the overall wage inequality that can be attributed to the sector. This is because the overall wage dispersion is much larger in the countries with firm-level wage setting. These countries have larger sector wage premiums, but they also have greater wage inequality coming from other sources.

My third result is that in countries with sector-level wage setting observable worker characteristics explain a larger fraction of the overall wage variance. Additionally, in these countries a greater fraction of workers is covered by collective bargaining. Countries with firm-level wage setting tend to have little collective bargaining and instead wages are bargained between each individual worker and the firm. Hence the result above is likely due to the fact that wages under collective bargaining are typically set using a formula that takes into account various observable characteristics of the worker i.e. occupation, tenure, years of

⁵However, Magda et al. (2011) include a number of firm characteristics such as firm size among the control variables. I consciously only control for worker and job characteristics, because the core idea of centralised wage setting is to equalise wages across heterogeneous firms. Thus I want all of the wage variation across sectors that is due to differences in average firm characteristics to be picked up by the sector dummy variables.

experience and education, whereas under individual wage bargaining other factors can also affect wages. These can be individual worker ability observed by the employer, but not by the econometrician, productivity of the firm and idiosyncratic productivity of the match.

This chapter is closely related to the literature on the relationship between centralisation of wage setting and the conditional dispersion of wages across sectors (Zweimuller and Barth (1994), Teulings and Hartog (1998)). I contribute to the literature in three ways. First, I highlight that sector-level wage setting combined with informal coordination of wages across sectors seems to be sufficient to obtain a relatively compressed distribution of (conditional) inter-industry wage differentials. In the past this was observed only for countries with formal, enforced coordination of wages across all private sector industries. Second, in addition to using the traditional method of estimating industry wage differentials I also perform regression-based variance decomposition to assess the relative importance of sector for explaining wage inequality. Third, I provide a novel result that observable worker characteristics have greater predictive power for explaining wages in countries that have collective wage bargaining at the sector level.

1.2 Literature on Inter-Industry Wage Differentials

The idea that employers are important for explaining variation in wages has very long roots in labour economics. One of the earliest studies to document differences in wages across sectors for similar workers was Slichter (1950). In the late 1980s the interest in the topic was revived in a series of papers that focused on the US and estimated conditional industry wage differentials. The authors suggested that the structure of wages in the US was not consistent with a perfectly competitive labour market (Dickens (1987), Krueger and Summers (1988), Katz and Summers (1989), Thaler (1989)). According to the neo-classical model wage differences between sectors or firms are the result of either differences in worker quality (workers in the high paid sectors being more productive) or by the differences in the desirability of

different workplaces - the so called compensating wage differentials. Dickens (1987) and Krueger and Summers (1988) showed that some sectors were systematically paying higher wages than other sectors to workers with the same observable characteristics facing the same working conditions.

Since then similar results have been found for other industrialised countries. Benito (2000) for the United Kingdom, Hartog, Opstal, and Teulings (1997) for Netherlands, Gannon and Nolan (2004) for Ireland, Edin and Zetterberg (1992) for Sweden, Vainiomaki and Laaksonen (1995) for Finland, Hartog, Pereira, and Vieira (2000) for Portugal and Casado-Diaz and Simon (2008) for Spain. The existence of inter-industry wage differentials has become a stylised fact in labour economics. Furthermore, these sector wage differentials are persistent across time (Gittleman and Wolff (1993), Caju, Rycx, and Tojerow (2011)) and the ranking of sectors tends to be similar across countries (Caju, Lamo, et al. (2010)), but the size of the sector wage premiums varies a great deal across countries (Teulings and Hartog (1998)).

One country characteristic that has proven to be a strong predictor of the dispersion of industry wage premiums is the degree of centralisation of wage bargaining (Kahn (1998), Rycx (2002), Gannon, Plasman, et al. (2007)). Centralisation of wage bargaining captures the level at which wages are determined. Wage bargaining between representatives of unions and employers can take place at the level of the plant or the firm (the most decentralised case), at the level of the sector, or wages for each type of worker can be equalised across the entire private sector (the most centralised case). The sentiment behind centralisation of wage setting is equal pay for equal work and the main economic effect is to equalise wages across firms heterogeneous in productivity and profitability (Barth, Moene, and Willemsen (2014)). Zweimuller and Barth (1994) use data for the early 1980s and find 3-4 times smaller conditional inter-industry wage differentials in Austria, Norway and Sweden (countries at the time ranked as 1, 2 and 3 in the world in terms of centralisation of wage-setting) than in Canada and the USA where wage setting is completely decentralised. Teulings and

Hartog (1998) use data covering late 1980s and again find that from the most to the least centralised country the dispersion in conditional inter-industry wage differentials increases roughly at a ratio of 1:4. Similar result is found by Kahn (1998).

However, there is still no consensus on what is the fundamental economic force generating sector wage differentials. The first explanation is that the wage differentials are simply a reflection of differences in average worker quality across sectors, but we just cannot capture them because a significant portion of worker quality is unobservable (Murphy and Topel (1987)). Within each education, experience and occupation subgroup workers are going to vary in productivity. The high wage sectors are paying a premium because they are trying to attract the best workers. The equilibrium models of sorting imply that if there are complementarities in production between worker and firm quality then there will be positive assortative matching where the most skilled workers sort themselves into the most productive firms (Becker (1973), Shimer and L. Smith (2000)).

The second explanation is that the sector wage premiums are the result of differences in wage policies across firms, i.e. some firms are paying higher wages for identical workers than other firms. Firstly, this could be because of rent sharing. Firms differ in profitability due to variation in technical efficiency (TFP) and differences in the extent of monopoly power. Workers have a certain degree of bargaining power because they are costly to replace (due to search frictions) and because they could go on a strike and they use this power to extract rents from firms. Secondly, the sector wage premiums could be the result of efficiency wages, firms in some sectors paying more than the market rate in order to reduce the labour turnover costs or to motivate workers and make them more productive.

A natural way of controlling for the worker unobservable ability is to use panel data and to examine changes in wages as workers switch between industries. However, there is a problem that transitions between different sectors might not be exogenous. Gibbons and Katz (1992) deal with this issue by limiting their attention to workers who lost their job because of a plant closure. They show using the US data that the dispersion of the inter-

industry wage differentials does not significantly decrease when estimating wage equations in first differences rather than in levels. This challenges the view that industry wage differentials are driven by differences in unmeasured ability.

Abowd, Kramarz, and Margolis (1999) use French linked employee-employer panel data to decompose the total variance of log wages into the contribution of time-invariant worker ability (worker fixed effects) and the time-invariant firm productivity (firm fixed effect). They find that the person effects explain about 90% of the inter-industry wage differentials. Similar result with French data is found by Goux and Maurin (1999). However, applying the same methodology to the administrative data for the US state of Washington Abowd and Kramarz (1999) found that inter-industry wage differentials are in equal proportions due to worker and firm heterogeneity.

The rent sharing hypothesis is supported by the fact that in industries in which one occupation is highly paid (conditional on worker and job characteristics), all occupations tend to be highly paid (Katz and Summers (1989)). It is unlikely that the high paying sectors would be choosing the best quality workers in every occupation group, including low-skilled occupations like cleaners or janitors and that is why they pay a wage premium for every occupation category. It is more likely that these wage premiums are due to wage policies that apply to all employees.

Martins (2004) uses Portuguese data and employs quantile regressions technique to estimate industry wage differentials at the 90th, 50th and 10th percentile of the wage distribution while controlling for worker, job and employer characteristics. Martins (2004) suggests that if the industry wage differentials are driven by differences in unobservable ability then industries with high average premia will have even higher wage premia for workers at the top of the conditional wage distributions, which is precisely where the highest unobserved ability workers would be expected to be found. Therefore sectors with high mean premiums should have very large differences in the premia between the top and the bottom of the conditional wage distribution. Instead Martins (2004) finds that the high wage sectors have approxi-

mately equally large premia at all points in the conditional wage distribution, challenging the unobservable ability narrative.

Caju, Lamo, et al. (2010) also estimate quantile regressions using the 1995 and 2002 issues of the Structure of Earnings Survey and find that in a sample of 8 European countries "in most instances the (sector) wage differentials are higher at the lower end of the distribution (10th percentile) than at the top end of the distribution (90th percentile), which goes against the unobserved quality hypothesis".

Furthermore, it has been shown that sector wage premiums are positively correlated with average firm profitability which is consistent with the rent sharing narrative (Katz and Summers (1989), Gannon, Plasman, et al. (2007)). Caju, Lamo, et al. (2010) find that sector wage premiums are positively correlated with a measure of sector rents, with a measure of monopoly power or market concentration in the industry and also with the share of firms covered by firm-level wage collective agreements. This evidence again supports the rent-sharing explanation of inter-industry wage differentials.

In conclusion, there seems to be a great deal of evidence in support of the rent-sharing hypothesis, but the role of unobservable worker quality differences between sectors cannot be completely ruled out.

1.3 Institutional Background: Coordination of Wage Bargaining Across Industries

Barth and Moene (2013) show that highly centralised wage bargaining emerged in a number of small, open European economies (the best examples being Sweden, Norway and Austria) in the post-war period due to a widely shared concern about maintaining international competitiveness. While wage increases in the sheltered industries can be passed on to higher prices, in the export-oriented manufacturing prices are set at international markets. Therefore the cost of higher wages in terms of decline in employment is much larger in the tradable

sector. Both employers and unions in the tradable sector understood that wages can only rise in line with productivity and growth in prices of internationally-traded goods. However, an unchecked growth in wages in the sheltered sectors imposes a negative externality on both firms and workers in the tradable sector: higher prices of domestic goods increase the general cost of living and also increase the cost of domestic inputs in the production of exports (Swenson (1991)). For this reason a cross-class coalition of unions in the manufacturing sector and employers in all sectors emerged and imposed centralised national-level wage setting in order to ensure that wage growth in the sheltered industries is never above the one in the tradable sector (Due et al. (1994), Ibsen (2015)). As part of this framework wages for each occupation were set for the entire private sector. Unions in the sheltered industries were prevented from leaving the centralized negotiations by the threat of lockouts (Barth and Moene (2013)).

However, the period of national-level wage bargaining came to an end in 1980s when several countries moved to sector-level wage bargaining (Ortigueira (2013)). There was concern at the time that this would lead to the worst of both worlds, as sector-level unions are powerful enough to push for wage increases, but not all-encompassing enough to internalize the resulting negative externalities (Calmfors and Driffil (1988)). Hence, according to this argument, either completely decentralised or the most centralised wage bargaining are better in terms of efficiency. What emerged in response to the need for wage moderation was a system of pattern bargaining where the export-oriented manufacturing sector undertakes wage bargaining first and the resulting pay increase becomes the norm for the rest of the economy (Ibsen (2016)). This informal institutional set-up helps countries limit wage growth in the sheltered industries and maintain international competitiveness (Johnston, Hancke, and Pant (2014)). Furthermore, wage bargaining that is more coordinated across sectors is associated with lower unemployment and greater labour market resilience in the face of an economic downturn (OECD (2019)). Pattern bargaining is prominent in Norway, Sweden, Denmark, Finland, Netherlands, Germany and Austria. On the other hand, coor-

dination of wages across industries is achieved via state intervention in the case of Belgium (OECD (2019)).

Unlike the old national-level wage setting system, the pattern bargaining does not have obvious forms of enforcement (Traxler, Brandl, and Glassner (2008)). Nergaard (2014) finds that in Norway "the trend setting model is based on voluntary measures, tradition and common agreement among the labour market parties and the government". Ibsen (2015) suggest that while in Denmark the national-level confederation of unions can effectively veto agreements negotiated by the sector-level unions, in Sweden "the only sanctions against defections are naming and shaming and symbolic fines". Ibsen (2016) suggests that the internal stability of pattern bargaining cannot be explained solely through the rational self-interest of the different players and the resulting alliances. Instead Ibsen (2016) highlights the role of public mediation institutions that once established tend to sustain themselves and are useful in solving collective action problems. The ongoing existence of such informal coordination of wage setting across industries is a fascinating phenomena warranting future research. What I show in this chapter is that the combination of wage setting at sector level with some form of informal coordination of wage setting across sectors seems to be sufficient to maintain small inter-industry wage premiums.

1.4 Data

I use the Eurostat's Structure of Earnings Survey (SES) which is a unique dataset in that it contains harmonised multi-country linked employee-employer data and thus enables me to obtain estimates that are consistent and comparable across the European countries. I use the 2006, 2010 and 2014 issues of this cross-sectional establishment survey.

The SES contains harmonised data on worker gross earnings (annual, monthly and hourly), characteristics of workers (age, gender, the highest level of education, tenure, occupation), characteristics of jobs (permanent vs temporary contract, part time vs full time)

and characteristics of the firms (e.g. size of the firm). Descriptions of all the variables that I use in my estimations are in Table 1.1.

In each country a sample of plants is selected by stratified random sampling (stratification is done by economic activity, size and region) and within plants a random sample of employees is chosen. The data is representative of all establishments with at least 10 employees operating in all areas of the economy except public administration.

The first advantage of the SES is that it is standardised across countries, so that it contains the same variables that are defined in the same way. Secondly, it is a survey of establishments and thus should have a smaller measurement error than household studies. Thirdly, the sample sizes are very large, ranging from 100 000 to over a million.

The SES collects information about sector affiliation of the plants at two-digit level of the NACE classification (The Statistical Classification of Economic Activities in the European Community). However, during the anonymisation process the data on sector is aggregated so that no individual employee or firm could be identified from the data. Therefore the sector categories that I have access to are in between 1- and 2-digit in terms of aggregation. Overall there are 30 industry categories. I remove three of them for the reasons explained below and thus I am left with 27 sector categories. An advantage of these more aggregated categories is that they are consistent across time. The underlying data on industry affiliation follows NACE Rev 1.1 specification in 2006 and Nace Rev.2 in 2010 and 2014. However, the 2-digit categories are grouped into the more aggregated categories in the same way in all three years. The sector categories that I employ in my estimations are listed in Table 1.2.

The focus of this chapter is on the relationship between the type of wage bargaining in the private sector and the dispersion of wages across sectors. It is quite common that the public sector pays lower wages than the private sector for workers with the same characteristics performing similar jobs in exchange for better job security and more generous pensions. I do not want this to affect my comparison of the importance of sector for wage dispersion across countries. Therefore I remove all observations relating to Public Administration, Education,

Health and Social Care sectors from my analysis. I am still left with some establishments with public sector ownership in my sample, e.g. in the manufacturing industry or in electricity and water supply. I control for the possible effects of the difference in ownership of the establishment on wages by including a dummy variable for public sector ownership.

1.5 Methodology

1.5.1 Estimating Conditional Industry Wage Differentials

In estimating conditional industry wage differentials I follow the standard methodology first proposed by Krueger and Summers (1988). First, I estimate the following Mincer-type wage equation (Mincer (1974)) for each country-year pair.

$$\ln w_i = \alpha + \sum_{j=1}^J \beta_j X_{j,i} + \sum_{m=1}^M \lambda_m I_{m,i} + \epsilon_i \quad (1.1)$$

where w_i is the hourly wage of worker i , X contains worker and job characteristics: education (6 categories in 2006 and 4 categories in 2010 and 2014), age (6 categories), gender, tenure (continuous variable), occupation (approx 23 categories in 2006 and approx 50 categories in 2010 and 2014), full time vs part-time employment, permanent vs temporary contract. Additionally, I also control for whether the establishment is privately owned or it is owned by the state. This is to control for differences in wage policies in the public vs private sector. I comprises dummy variables relating to the sector affiliation of the establishments. More detail on all of the variables above is in Table 1.1. α is intercept, β_j and λ_m are parameters to be estimated and ϵ_i is an error term.

The parameters of interest are the λ_m where $m=1 \dots M$ denotes the industry category. There are 27 sector categories, one omitted, so I obtain 26 OLS coefficients. Following Krueger and Summers (1988) the estimated industry dummy coefficients λ_m are normalized as deviations from the employment-weighted mean industry coefficient. The advantages of

this approach are twofold: Wage differentials become independent of the arbitrarily chosen omitted industry category and therefore can be directly compared across studies using different base industries. Second, the normalized industry differentials express wage differences with respect to the average employee in the whole economy, rather than relative to some arbitrary group of employees and thus are easier to interpret.

$$\begin{aligned} d_m &= \lambda_m - \pi & \text{for } m = 1 \dots M \\ d_{M+1} &= \lambda_{M+1} - \pi = -\pi \end{aligned} \tag{1.2}$$

In (1.2) d_m is the normalized wage differential for industry m , λ_m is the estimated coefficient for dummy variable of industry m , $M=26$ is the number of included industry dummy variables and π is the employment-weighted mean industry coefficient defined as

$$\pi = \sum_{m=1}^M s_m \lambda_m \quad \text{for } m = 1 \dots M \tag{1.3}$$

where s_m is the employment share of sector m in the observed sample.

d_m tells us the wage premium for a worker employed in sector m compared to the economy-wide average for a worker with the same characteristics employed in a job with the same characteristics.

I follow the standard practise in the literature and for each country-year pair I calculate the Employment-Weighted Adjusted Standard Deviation (WASD) of inter-industry wage differentials given in (1.4).

$$\begin{aligned} WASD(d_m) &= \sqrt{\text{variance} - \text{correction term for sampling error}} \\ &= \sqrt{\sum_{m=1}^M s_m \left(d_m - \frac{\sum_{m=1}^M d_m}{M} \right)^2 - \frac{\sum_{m=1}^M \text{var}(d_m)}{M}} \end{aligned} \tag{1.4}$$

where $var(d_m)$ is the square of the standard error of industry wage differential for industry m .

The reason why I do not use a simple standard deviation, but instead each deviation from the mean is weighted by the employment share of that sector, is to take into account the fact that some sectors are much larger than others. We want to have a measure that is a good summary of the extent to which wages vary across sectors in the economy after controlling for worker and job characteristics. If a certain sector pays very large wage premium, but is extremely small in terms of employment, we do not want that to excessively inflate the measure of dispersion.

WASD also contains a correction term for sampling error. The need for this was first suggested by Krueger and Summers (1988). Although for each industry $m = (1, \dots, M)$ the estimated wage differential $(\widehat{\beta}_m)$ is an unbiased estimate of the true wage differential β_m , the standard deviation of $\widehat{\beta}$ is an upwardly biased estimate of the standard deviation of β . This bias occurs because $\widehat{\beta}_m = \beta_m + \widehat{\epsilon}_m$ where $\widehat{\epsilon}_m$ is a least squares sampling error. However, in my regressions the sample sizes are very large, so the sampling error is insignificant. Still, I calculate the measure of dispersion of sector wage premiums in the usual way to be maximally comparable with the previous literature.

1.5.2 Regression-based Variance Decomposition

I follow a regression-based variance decomposition approach proposed by Fields (2003). We start with the income-generating function in which the log of income is function of a number of explanatory factors.

$$\ln y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_J x_K + \epsilon \quad (1.5)$$

This can be rewritten as:

$$\ln y = \beta_0 + z_1 + z_2 + \dots + z_J + \epsilon \quad (1.6)$$

where each z_j is a "composite variable", equal to the product of a regression coefficient and its variable. We can estimate the model using OLS and decompose the inequality in log wages into the contribution of each composite variable and the residual term.

Fields (2003) shows that we can find "relative factor inequality weight" S_j as:

$$S_j(\ln y) = \frac{\text{cov}(z_j, \ln y)}{\sigma^2(\ln y)} = \frac{\text{cov}(\beta_j x_j, \ln y)}{\sigma^2(\ln y)} \quad (1.7)$$

S_j gives the fraction of the log-variance of wages that is attributable to the j 'th explanatory factor. By definition the relative shares must sum to 1.

$$\sum_{j=1}^{J+2} S_j(\ln y) = 1 \quad (1.8)$$

When excluding the last composite variable, which is the residual, the sum of the relative shares is equal to R^2 :

$$\sum_{j=1}^{J+1} S_j(\ln y) = R^2(\ln y) \quad (1.9)$$

We can also decompose the predicted values (variance of the log wages explained by the regression model) into the contribution of each explanatory factor. The share of the explained variance of $\ln y$ that is attributable to the j 'th explanatory factor is given by $P_j(\ln y)$

$$P_j(\ln y) = \frac{S_j(\ln y)}{R^2(\ln y)} \quad (1.10)$$

In my estimations the income generating function is given by (1.1) where the explanatory variables are worker and job characteristics and sector categories. I apply the methodology above to assess the relative importance of sector for wage dispersion across European coun-

tries.

1.6 Results

1.6.1 Dispersion of conditional industry wage differentials

I estimate Mincer wage regression given by (1.1) for each country-year pair and obtain OLS coefficients on the industry dummy variables. Because my sample sizes are very large these coefficients are estimated very precisely, overwhelming majority of them are statistically significant at 5% level. Next I normalise them, as shown in (1.2), to obtain inter-industry wage differentials. These tell us the wage premium for a worker employed in the given sector compared to the economy-wide average for a worker with the same characteristics employed in a job with the same characteristics. These conditional industry wage differentials can be positive or negative. Some sectors pay higher and some sectors pay lower wages than the economy-wide average conditional on worker and job characteristics.

For each country-year pair I calculate a measure of the conditional dispersion of wages across different industries within the country. I follow the usual practise in the literature and obtain the Employment-Weighted Adjusted Standard Deviation (WASD) of inter-industry wage differentials given by (1.4). The number of included countries is 16 in 2006, 13 in 2010 and 15 in 2014. Unfortunately the variables I use are not available for all countries in all the years and hence the sample of countries varies slightly from year to year.

The weighted adjusted standard deviation of inter-industry wage differentials, the degree of centralisation and of coordination of wage bargaining and collective bargaining coverage for each country for the years 2014, 2010 and 2006 are displayed in Table 1.3, Table 1.4 and Table 1.5 respectively. Countries are ranked in terms of the size of the dispersion. We can see that at the top of the rankings with the greatest dispersion of sector wage premiums are the Central and Eastern European (CCE) countries, i.e. Bulgaria, Romania, Slovakia, Czech Republic, Latvia, Lithuania, but also the United Kingdom. At the bottom of the

rankings are countries in Western Europe, such as Belgium, France, Sweden and Finland. This East-West contrast in Europe is also found by Magda et al. (2011). The ranking of countries seems to be very persistent across time. The differences between countries in terms of the importance of industry for wages are substantial. For example in 2014 the dispersion of industry wage differentials was almost 3 times larger in Bulgaria than in Belgium and it was twice as large in Romania than in Finland.

This sharp geographical divide in terms of the dispersion of wages across sectors can be explained by differences in wage setting institutions. We can see from Tables 1.3, 1.4 and 1.5 that the countries with the smallest dispersion tend to have wage bargaining that is highly centralised and also highly coordinated across the economy⁶. They also tend to have high levels of collective bargaining coverage.

In the Western European countries the main level at which wage bargaining takes place is the sector and there is typically also informal coordination of wages across sectors. In contrast, the CCE countries and the UK have wage setting mostly at the firm-level and there is very little coordination of wages across sectors. While over 90% of workers in Belgium, Finland or France are covered by some type of collective wage agreement, in the CCE countries and the UK only a minority of workers have their wages collectively negotiated.

From Table 1.6 we can see that the dispersion of industry wage differentials is strongly negatively correlated with indexes of centralisation and coordination of wage bargaining and with collective bargaining coverage (all three measures come from Visser (2016)). Depending on the year the correlation coefficient between WASD and the degree of centralisation varies between -0.64 and -0.76. For the degree of coordination the correlation coefficient varies between -0.64 and -0.71. Finally, for collective bargaining coverage it varies between -0.82 and -0.90.

This inverse relationship between the degree of centralisation and coordination of wage bargaining and collective bargaining coverage on one hand, and the dispersion of industry

⁶The rankings come from the Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts by J. Visser.

wage premiums on the other, can also be seen in the scatter plots shown in Figures 1.1(a)-1.3(c).

1.6.2 Regression-based Variance Decomposition

In addition to evaluating the dispersion of sector wage premiums I employ regression-based variance decomposition proposed by Fields (2003) in order to understand the relative importance of sector for wage dispersion⁷. This chapter is the first in the literature on industry wage premiums to use this method. The full results for the years 2014, 2010 and 2006 are displayed in Table 1.15, Table 1.16 and Table 1.17 respectively.

Following Fields (2003) I decompose the variance of the dependent variable, the log of hourly wages, into the share accounted for by each explanatory variable and by the residual. My first new measure of the importance of sector in a given country is the percentage share of the inequality of log hourly wages that can be accounted for by the sector categories given by (1.7). I calculate this relative share for each country-year pair.

I find that this measure, while moderately correlated with the dispersion of industry wage differentials (WASD), is no longer clearly inversely related to the degree of centralisation and coordination of wage setting and with the collective bargaining coverage (see Table 1.7). The correlation between this relative share and WASD ranges between 0.5 and 0.74 depending on the year. Correlation coefficient for centralisation ranges between -0.21 and -0.35. For coordination it is between -0.03 and -0.27. Finally, for bargaining coverage it varies from -0.26 to -0.54.

Hence I find that while the absolute dispersion of wages across different sectors of the economy is much smaller in the countries with more centralised and coordinated wage setting, the share of the overall inequality of wages that can be attributed to sector is not necessarily smaller. The two measures are conceptually different and therefore it is not completely surprising that they give a different picture.

⁷I use Stata module INEQRBD developed by Fiorio and Jenkins (2010) that applies Fields's regression-based inequality decomposition.

I find that the countries with less centralisation and coordination of wage setting generally have much larger total dispersion of wages (see Table 1.10). Therefore these countries have larger sector wage premiums, but they also have more inequality coming from other sources. Additionally, the countries with decentralised wage setting tend to have very large residual wage dispersion, wage variance that is not explained by worker and job characteristics or by industry categories (see Table 1.11(a)).

In response to the findings above I also consider an alternative measure of the relative importance of sector for wage dispersion which is the percentage share of the explained variance (variance explained by the regression model) that can be attributed to industry categories. This measure is equal to the relative inequality share from above divided by the R^2 of the regression (see 1.10). It captures the importance of industry relative to the other explanatory factors, i.e. worker and job characteristics.

Table 1.8 shows that the share of the explained variance attributable to sector and the dispersion of inter-industry wage differentials are very strongly correlated. The correlation coefficient ranges between 0.71 and 0.96 depending on the year. Furthermore, this measure of the relative importance of sector is also moderately negatively correlated with the degree of centralisation and coordination of wage setting and with collective bargaining coverage. The correlation coefficients are typically twice as large as for the previous measure of the relative role of sector for wage dispersion.

Next, I use the estimates from the regression-based variance decomposition of log hourly wages to derive a measure of the absolute variance of wages that is accounted for by sector. I use this measure as an alternative to the standard deviation of industry wage differentials, to check my findings. I calculate it as the product of the share of the variance of log hourly wages accounted by sector and of the standard deviation of log hourly wages. We can see from Table 1.9 that this measure is very closely associated with the dispersion of industry wage differentials, the correlation coefficient ranges between 0.76 and 0.92. This measure of the absolute importance of sector for wage dispersion is also strongly inversely related to the

degree of centralisation and coordination of wage setting and collective bargaining coverage. Thus I confirm my result from Section 1.6.1.

Finally, I find that in countries with more centralised and coordinated wage setting where greater share of workers are covered by collective bargaining, worker characteristics explain a greater share of the wage dispersion. I run regression for the same countries as before where the dependent variable is log hourly wages and explanatory variables are only those worker characteristics that are likely to be part of collective wage agreements: education, age (proxy for years of work experience), tenure and occupation. Correlations between R^2 from this regression and wage setting institutions are displayed in Table 1.11(b). Depending on the year the correlation coefficient between R^2 and the degree of centralisation varies between 0.6 and 0.66. For the degree of coordination the correlation coefficient varies between 0.6 and 0.76. Finally, for collective bargaining coverage it varies between 0.59 and 0.7. R^2 of both the baseline and the worker-characteristics-only regressions for all the countries are shown in Table 1.12-1.14.

1.6.3 Discussion of the results

My first result is that the degree of centralisation of wage setting and the dispersion of industry wage premiums are negatively correlated across the European countries. This is in line with the previous studies that used data for 1980s (Zweimuller and Barth (1994), Teulings and Hartog (1998)). However, there has been a substantial move towards decentralisation of wage bargaining in almost all European countries since 1980s (Ortigueira (2013)). Whereas between 1950s and 1980s, in a number of countries, most notably in Sweden, Norway and Austria, trade union and employer confederations representing all the workers and firms in the private sector were setting standardised wages for each occupation across all the industries, these days the main level at which wages are set is either a particular industry or a particular firm (Calmfors (2001), Ortigueira (2013)). Countries in my sample that came closest to having national-level wage setting between 2006 and 2014 were Belgium,

Finland and Greece (Visser (2016)). However, in these countries only a certain average level of wage growth is determined at national-level whereas actual wages for each occupation are set predominantly at sector-level. Thus the inverse relationship between the degree of centralisation and the dispersion of inter-industry wage differentials seems to hold even when comparing medium and low levels of centralisation.

In other words I find that in countries where the main level for wage bargaining is the sector the dispersion of wages across sectors after controlling for detailed worker and job characteristics is substantially smaller than in countries where wage bargaining occurs predominantly at the firm level. This is a priori not obvious given that sector-level wage setting implies only equalising wages for each worker type across heterogeneous firms within the same sector.

However, I find that the size of sector wage premiums in a given country is also negatively correlated with an index that captures the degree of coordination of wage bargaining in that country. In my sample the countries that have the lowest dispersion of inter-industry wage differentials across all the years are Belgium, France, Sweden, Finland and Netherlands. All of these except for France have very high degree of coordination of wage setting across industries. In the case of Belgium this is achieved via state intervention where wages are indexed to increases in living costs, but at the same time wage increases are not allowed to exceed a weighted-average of the wage growth in the country's main trading partners (OECD (2019)). In the case of Sweden, Finland and Netherlands, high degree of coordination of wage setting across industries is the result of more informal, almost voluntary system called pattern bargaining.

Under pattern bargaining one sector, typically export-oriented manufacturing, undertakes wage bargaining first and the resulting wage increase acts as an upper bound for wage increases in other sectors (Traxler, Brandl, and Glassner (2008)). There is no legislation or government regulation enforcing pattern bargaining. Instead it is supported by a shared understanding of the need to maintain international competitiveness, the existence of tra-

dition and of public mediation institutions (Ibsen (2016))⁸. This suggests that sector-level wage bargaining in combination with informal coordination of wages across sectors is often sufficient to maintain a relatively compressed distribution of (conditional) inter-industry wage differentials. This is a novel result, the previous studies only found small industry wage premiums for countries that had wage setting at the level of the entire private sector and thus had formal, enforced coordination of wages across industries (Zweimuller and Barth (1994), Kahn (1998)). However, a certain degree of centralisation of wage setting (sector-level bargaining) seems to be necessary, as there are no examples of countries with firm-level bargaining that would be ranked as having a high degree of coordination of wage setting across different parts of the economy. It seems that coordination only works once the number of bargaining units has been reduced via centralisation⁹.

My second result is that the relative share of the overall wage inequality that can be attributed to the sector that a worker is employed in is not generally larger in the countries with firm-level wage setting. This is because the overall wage dispersion is larger in the countries with firm-level wage setting. While countries with decentralised and uncoordinated wage bargaining tend to have larger industry wage differentials, they also have more wage inequality coming from other sources. For this reason I introduce a new measure of the relative importance of sector for wage dispersion which is the share of the explained variance accounted for by sector categories. With this measure I do find that sector is a relatively more important explanatory factor in countries with firm-level bargaining.

Thirdly, I find that worker observable characteristics, specifically education, age, tenure and occupation, explain a greater fraction of the overall wage dispersion in countries with more centralised (sector-level) wage setting. This is because these countries also tend to have a larger share of the workers covered by collective bargaining. On the contrary, in countries with predominantly firm-level wage setting individual bargaining tends to dominate and

⁸More detailed discussion is in Section 1.3.

⁹The bargaining unit under individual wage bargaining is the match between the worker and the firm. With collective bargaining at firm-level the bargaining unit is the firm. Under sector-level wage setting the bargaining unit is the sector.

collective bargaining plays only a very small role. Wages under collective bargaining are typically calculated using a formula that takes into account various observable characteristics of the worker i.e. occupation, tenure, years of experience and education, whereas under individual wage bargaining other factors (e.g. worker ability observed by the employer, but not by the econometrician, productivity of the firm, idiosyncratic productivity of the match) can also affect wages.

1.7 Conclusion

I find that in countries where wage setting is more centralised (the main level for wage bargaining is the sector) the dispersion of wages across sectors after controlling for worker and job characteristics is substantially smaller than in countries where wage bargaining occurs predominantly at the firm or plant level. This is surprising given that sector-level bargaining implies only equalising wages for each worker type within industries. I find that countries with smaller dispersion of (conditional) inter-industry wage differentials also tend to have higher degree of coordination of wage setting across different parts of the economy. Thus it seems that sector-level wage bargaining combined with coordination of wage bargaining across sectors is sufficient to maintain a compressed distribution of sector wage premiums. This is a novel result given that the previous studies only found small dispersion of inter-industry wage differentials in countries that had the most centralised (national-level) wage setting (Zweimuller and Barth (1994), Kahn (1998)).

Some countries (e.g. Belgium) achieve high degree of coordination via state intervention, but others (Sweden, Finland, Netherlands, Norway) do so via more informal setup of pattern bargaining. Under pattern bargaining one sector negotiates the rate of wage increases first and this becomes a benchmark for negotiators in the other sectors. However, having sector as the main level at which wage bargaining takes place seems to be a necessary precondition for effective coordination of wage setting and for limiting the size of sector wage premiums.

There are no countries with firm-level wage bargaining that would be ranked as having a high degree of coordination of wage setting across industries. Coordination only works once the number of bargaining units has been reduced via centralisation.

While countries with sector-level wage setting tend to have smaller sector wage premiums, the share of the overall wage inequality that can be attributed to the sector that a worker is employed in is not generally smaller in the countries with more centralised wage setting. This is because countries with decentralised and uncoordinated wage setting have larger overall earnings inequality. Thus they also have greater wage inequality coming from other sources. Finally, I find that worker characteristics explain a greater share of wage variance in countries with sector-level wage setting. This is intuitive as these countries also have greater share of the employees covered by collective wage agreements where wages are usually a function of characteristics such as occupation, tenure, education and years of work experience.

Tables

Table 1.1: Description of the variables

Variable	Description
Gross hourly wage	Gross earnings for the reference month (before taxes and social security contributions) are divided by the number of paid hours during the month
Industry categories	NACE Rev.2, 27 categories
Education	the highest completed level of education, following International Standard Classification of Education, 6 categories in 2006 and 4 categories in 2010 and 2014
Age	6 categories
Gender	dummy variable
Tenure	the number of years in the same firm, continuous variable
Occupation	following International Standard Classification of Occupations (ISCO-08), approx 23 categories in 2006, approx 50 categories in 2010 and 2014
Working full-time	dummy variable
Type of employment contract	3 categories: permanent, temporary, apprentice
Ownership of the establishment	public or private, dummy variable

Table 1.2: Sector Categories

- 1 Manufacture of food products, beverages and tobacco products
- 2 Manufacture of textiles
- 3 Manufacture of wearing apparel, leather and related products
- 4 Manufacture of wood and of products of wood and cork
- 5 Publishing, printing and reproduction of recorded media
- 6 Manufacture of coke and refined petroleum products, chemicals, rubber and plastic products
- 7 Manufacture of basic pharmaceutical products and pharmaceutical preparations
- 8 Manufacture of other non-metallic mineral products
- 9 Manufacture of basic and fabricated metal products, except machinery and equipment
- 10 Manufacture of computer, electronic and optical products
- 11 Manufacture of machinery and equipment
- 12 Manufacture of motor vehicles and other transport equipment
- 13 Other manufacturing
- 14 Electricity, gas and water supply
- 15 Waste collection
- 16 Wholesale trade
- 17 Retail trade
- 18 Transport and warehousing
- 19 Postal and courier activities, telecommunications, computer programming, travel agencies
- 20 Financial services
- 21 Real estate, leasing, research and development, advertising
- 22 Business support activities
- 23 Recreational, cultural and sporting activities
- 24 Activities of membership organisations e.g. Church
- 25 Mining
- 26 Construction
- 27 Hotels and Restaurants

Table 1.3: The dispersion of industry wage differentials (2014)

Country	WASD	Centralisation	Coordination	Bargaining Coverage
Bulgaria	0.133	2	2	29
Romania	0.119	1.8	2.4	35
United Kingdom	0.106	1	1	30
Slovakia	0.106	2	2.4	25
Czech Republic	0.103	1	2	47
Poland	0.103	1	1	15
Norway	0.101	3	4	67
Latvia	0.092	1	1	15
Italy	0.08	3	3	80
Spain	0.076	3	3	78
Netherlands	0.074	3	4	85
Sweden	0.063	3	4	89
France	0.063	3	2	98
Finland	0.062	4.2	4.6	93
Belgium	0.046	4.8	5	96

WASD is the employment-weighted adjusted standard deviation of inter-industry wage differentials. All three measures of wage setting institutions come from Visser (2016). The centralisation and coordination indexes both take values from 1 to 5, 5 being the most centralised (the most coordinated). The bargaining coverage gives the share of all workers in the country that are covered by some type of collective agreement.

Table 1.4: The dispersion of industry wage differentials (2010)

Country	WASD	Centralisation	Coordination	Bargaining Coverage
Bulgaria	0.138	2	2	33
United Kingdom	0.121	1	1	31
Slovakia	0.119	2	2.2	38
Latvia	0.105	1	1	18
Czech Republic	0.101	1	2	51
Norway	0.091	3	4	68
Spain	0.079	3	3.4	77
Greece	0.078	4.8	4.2	64
Netherlands	0.076	3	4	90
Finland	0.069	3.3	3.4	78
Sweden	0.057	3	4	88
France	0.057	3	2	98
Belgium	0.045	4.6	5	96

WASD is the employment-weighted adjusted standard deviation of inter-industry wage differentials. All three measures of wage setting institutions come from Visser (2016). The centralisation and coordination indexes both take values from 1 to 5, 5 being the most centralised (the most coordinated). The bargaining coverage gives the share of all workers in the country that are covered by some type of collective agreement.

Table 1.5: The dispersion of industry wage differentials (2006)

Country	WASD	Centralisation	Coordination	Bargaining Coverage
Bulgaria	0.17	2.6	2.4	35
Slovakia	0.163	2	1.4	40
Latvia	0.149	1	1	18
Lithuania	0.143	1	1	12
Poland	0.13	1	1	16
Czech Republic	0.119	1	2	50
United Kingdom	0.114	1	1	33
Estonia	0.093	1	2	25
Greece	0.089	4.6	4	82
Norway	0.088	3	4	70
Sweden	0.076	3	4	93
Netherlands	0.075	3.6	4	67
Spain	0.071	3	4	76
Finland	0.067	4.4	5	88
Belgium	0.06	4.6	5	96
France	0.053	3	2	98

WASD is the employment-weighted adjusted standard deviation of inter-industry wage differentials. All three measures of wage setting institutions come from Visser (2016). The centralisation and coordination indexes both take values from 1 to 5, 5 being the most centralised (the most coordinated). The bargaining coverage gives the share of all workers in the country that are covered by some type of collective agreement.

Table 1.6: The link between the dispersion of industry wage differentials and wage setting institutions

Correlation of WASD with:	2006	2010	2014
The degree of centralisation	-0.64	-0.72	-0.76
The degree of coordination	-0.71	-0.70	-0.64
Collective bargaining coverage	-0.82	-0.90	-0.84

Table 1.7: The relative importance of sector for wage dispersion and wage setting institutions

DEPSHARE (% share of the variance of the log of hourly wages that is explained by industry categories) correlated with:

	2006	2010	2014
The dispersion of industry wage differentials (WASD)	0.74	0.71	0.50
The degree of centralisation	-0.23	-0.35	-0.21
The degree of coordination	-0.27	-0.22	-0.03
Collective Bargaining Coverage	-0.39	-0.54	-0.26

Table 1.8: The relative importance of sector for wage dispersion and wage setting institutions

EXPSHARE(% share of the variance explained by the regression model that is due to industry categories) correlated with:

	2006	2010	2014
The dispersion of industry wage differentials (WASD)	0.96	0.87	0.71
The degree of centralisation	-0.47	-0.53	-0.45
The degree of coordination	-0.53	-0.47	-0.31
Collective Bargaining Coverage	-0.68	-0.79	-0.53

Table 1.9: The absolute importance of sector for wage dispersion and wage setting institutions

SD(ln hourly wage) * DEPSHARE (The absolute value of the dispersion of the log of hourly wages that is explained by industry categories) correlated with:

	2006	2010	2014
The dispersion of industry wage differentials (WASD)	0.92	0.89	0.76
The degree of centralisation	-0.45	-0.54	-0.48
The degree of coordination	-0.55	-0.48	-0.36
Collective Bargaining Coverage	-0.67	-0.73	-0.54

Table 1.10: Earnings inequality and wage setting institutions

STDEV of log hourly wages correlated with:

	2006	2010	2014
The degree of centralisation	-0.66	-0.63	-0.67
The degree of coordination	-0.76	-0.73	-0.77
Collective Bargaining Coverage	-0.82	-0.68	-0.66

Table 1.11: Fit of regression model and wage setting institutions

(a) Baseline regression

R^2 of the regression correlated with:

	2006	2010	2014
The degree of centralisation	0.53	0.56	0.62
The degree of coordination	0.55	0.73	0.69
Collective Bargaining Coverage	0.64	0.65	0.55

(b) Worker characteristics only

R^2 of the regression correlated with:

	2006	2010	2014
The degree of centralisation	0.60	0.62	0.66
The degree of coordination	0.60	0.76	0.72
Collective Bargaining Coverage	0.69	0.70	0.59

The dependent variable is log of hourly wage. Baseline regression includes education, age, gender, tenure, occupation, full-time status, type of contract, type of ownership of the plant and industry categories as explanatory variables. Worker characteristics only regression includes education, age, tenure and occupation.

Table 1.12: Fit of regression models (2014)

Country	R^2 baseline model	R^2 worker characteristics only
Belgium	0.81	0.79
Bulgaria	0.49	0.44
Czech Republic	0.59	0.52
Spain	0.50	0.46
Finland	0.64	0.59
France	0.50	0.46
Italy	0.49	0.44
Latvia	0.36	0.31
Netherlands	0.70	0.66
Norway	0.61	0.55
Poland	0.51	0.45
Romania	0.44	0.41
Sweden	0.53	0.49
Slovakia	0.50	0.44
United Kingdom	0.59	0.54

The dependent variable is log of hourly wage. Baseline regression is given by (1.1) and includes education, age, gender, tenure, occupation, full-time status, type of contract, type of ownership of the plant and industry categories as explanatory variables. Worker characteristics only regression includes education, age, tenure and occupation.

Table 1.13: Fit of regression models (2010)

Country	R^2 baseline model	R^2 worker characteristics only
Belgium	0.71	0.6747
Bulgaria	0.47	0.4198
Czech Republic	0.57	0.5032
Greece	0.55	0.5053
Spain	0.53	0.4817
Finland	0.59	0.5386
France	0.5	0.4579
Latvia	0.35	0.2677
Netherlands	0.66	0.5997
Norway	0.6	0.5434
Sweden	0.53	0.4926
Slovakia	0.52	0.4434
United Kingdom	0.55	0.4938

The dependent variable is log of hourly wage. Baseline regression is given by (1.1) and includes education, age, gender, tenure, occupation, full-time status, type of contract, type of ownership of the plant and industry categories as explanatory variables. Worker characteristics only regression includes education, age, tenure and occupation.

Table 1.14: Fit of regression models (2006)

Country	R^2 baseline model	R^2 worker characteristics only
Belgium	0.56	0.5089
Bulgaria	0.47	0.4023
Czech Republic	0.55	0.4554
Estonia	0.44	0.3775
Greece	0.55	0.507
Spain	0.48	0.4302
Finland	0.6	0.5242
France	0.52	0.4771
Latvia	0.3	0.2295
Lithuania	0.26	0.2151
Netherlands	0.51	0.4922
Norway	0.59	0.5315
Poland	0.5	0.4359
Sweden	0.53	0.4643
Slovakia	0.52	0.4164
United Kingdom	0.57	0.5225

The dependent variable is log of hourly wage. Baseline regression is given by (1.1) and includes education, age, gender, tenure, occupation, full-time status, type of contract, type of ownership of the plant and industry categories as explanatory variables. Worker characteristics only regression includes education, age, tenure and occupation.

Table 1.15: Regression-based Variance Decomposition (2014)

Country	DEPSHARE	σ	$\sigma^{industry}$	EXPSHARE
Belgium	2.87	0.368	0.011	3.54
Bulgaria	7.21	0.587	0.042	14.71
Czech Republic	5.01	0.473	0.024	8.55
Spain	4.07	0.489	0.020	8.10
Finland	5.16	0.357	0.018	8.09
France	2.81	0.516	0.015	5.67
Italy	4.03	0.542	0.022	8.20
Latvia	3.50	0.559	0.020	9.79
Netherlands	5.48	0.507	0.028	7.87
Norway	10.84	0.401	0.043	17.80
Poland	5.59	0.560	0.031	10.88
Romania	3.81	0.622	0.024	8.60
Sweden	4.70	0.335	0.016	8.85
Slovakia	5.39	0.499	0.027	10.74
United Kingdom	8.25	0.531	0.044	14.02

DEPSHARE is the % share of the variance of the log hourly wages that can be explained by industry categories. σ is standard deviation of log hourly wages. $\sigma^{industry} = (DEPSHARE/100) * \sigma$, it is the absolute value of the dispersion of the log hourly wages that is explained by industry categories. EXPSHARE is the % share of the variance explained by the regression model that is due to industry categories.

Table 1.16: Regression-based Variance Decomposition (2010)

Country	DEPSHARE	σ	$\sigma^{industry}$	EXPSHARE
Belgium	2.84	0.365	0.010	4.01
Bulgaria	7.51	0.594	0.045	15.83
Czech Republic	5.47	0.493	0.027	9.53
Greece	5.69	0.456	0.026	10.41
Spain	4.55	0.490	0.022	8.63
Finland	4.83	0.382	0.018	8.13
France	2.44	0.476	0.012	4.86
Latvia	4.14	0.610	0.025	11.95
Netherlands	5.08	0.550	0.028	7.72
Norway	9.89	0.386	0.038	16.38
Sweden	4.01	0.331	0.013	7.54
Slovakia	7.13	0.489	0.035	13.76
United Kingdom	8.92	0.555	0.049	16.20

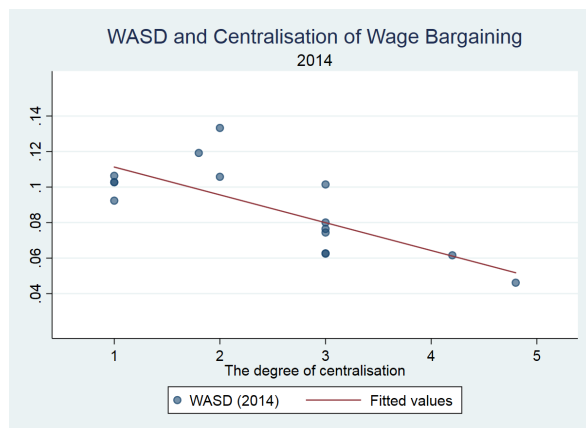
DEPSHARE is the % share of the variance of the log hourly wages that can be explained by industry categories. σ is standard deviation of log hourly wages. $\sigma^{industry} = (DEPSHARE/100) * \sigma$, it is the absolute value of the dispersion of the log hourly wages that is explained by industry categories. EXPSHARE is the % share of the variance explained by the regression model that is due to industry categories.

Table 1.17: Regression-based Variance Decomposition (2006)

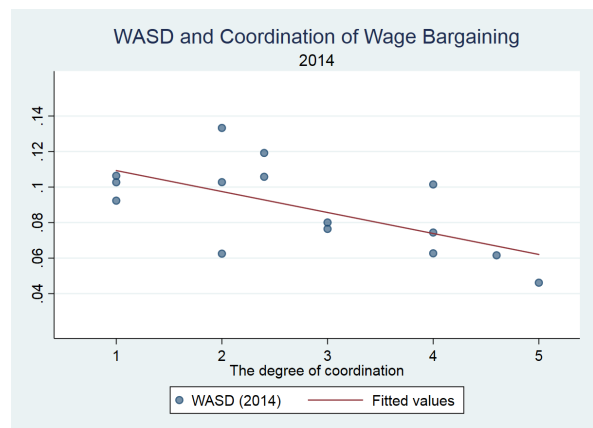
Country	DEPSHARE	σ	$\sigma^{industry}$	EXPSHARE
Belgium	5.10	0.356	0.018	9.16
Bulgaria	12.86	0.588	0.076	27.11
Czech Republic	9.38	0.472	0.044	17.05
Estonia	4.26	0.615	0.026	9.66
Greece	7.69	0.474	0.036	14.01
Spain	4.54	0.462	0.021	9.41
Finland	5.80	0.350	0.020	9.72
France	2.19	0.492	0.011	4.24
Latvia	7.12	0.621	0.044	23.17
Lithuania	5.31	0.700	0.037	20.49
Netherlands	4.68	0.589	0.028	9.15
Norway	9.72	0.343	0.033	16.43
Poland	8.60	0.580	0.050	17.02
Sweden	6.12	0.330	0.020	11.54
Slovakia	12.73	0.513	0.065	24.31
United Kingdom	8.68	0.553	0.048	15.18

DEPSHARE is the % share of the variance of the log hourly wages that can be explained by industry categories. σ is standard deviation of log hourly wages. $\sigma^{industry} = (DEPSHARE/100) * \sigma$, it is the absolute value of the dispersion of the log hourly wages that is explained by industry categories. EXPSHARE is the % share of the variance explained by the regression model that is due to industry categories.

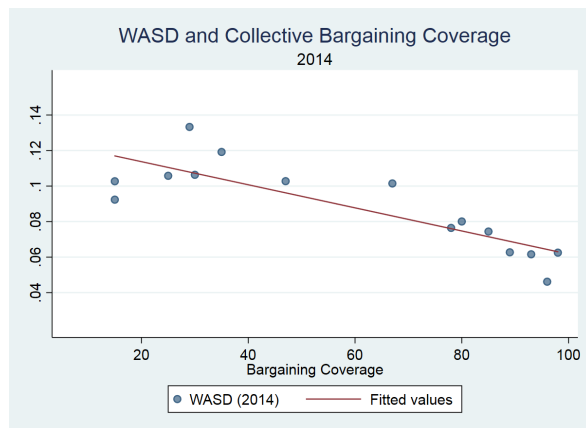
Figures



(a) WASD and Centralisation

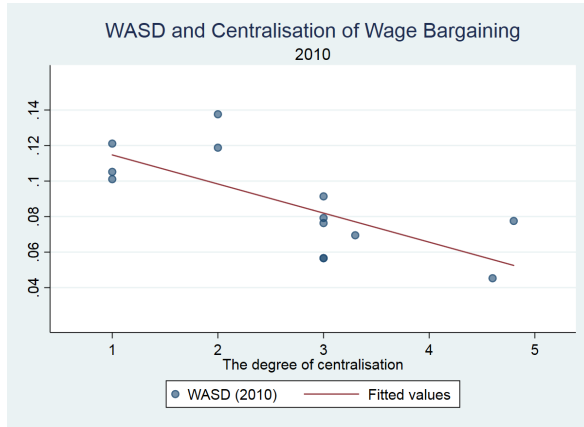


(b) WASD and Coordination

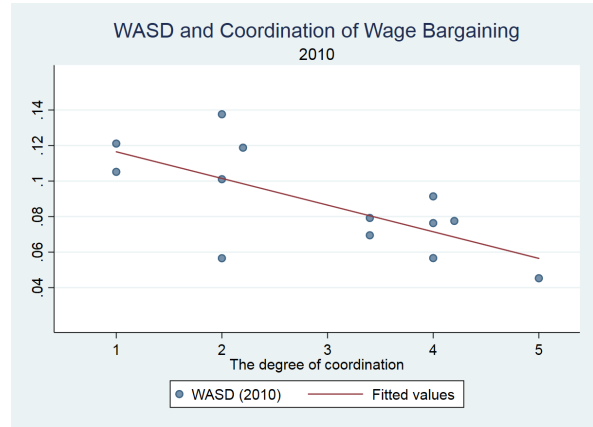


(c) WASD and Collective Bargaining Coverage

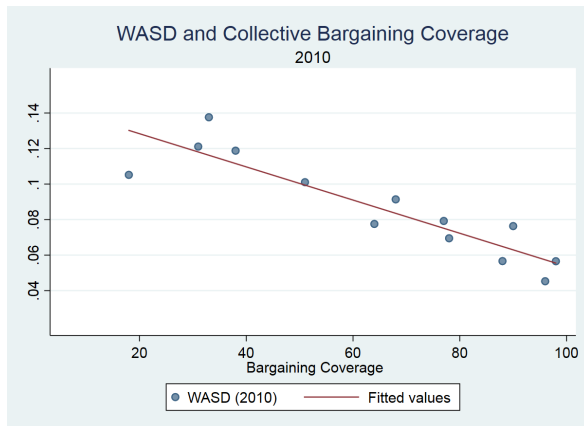
Figure 1.1: WASD and Wage Setting Institutions (2014)



(a) WASD and Centralisation

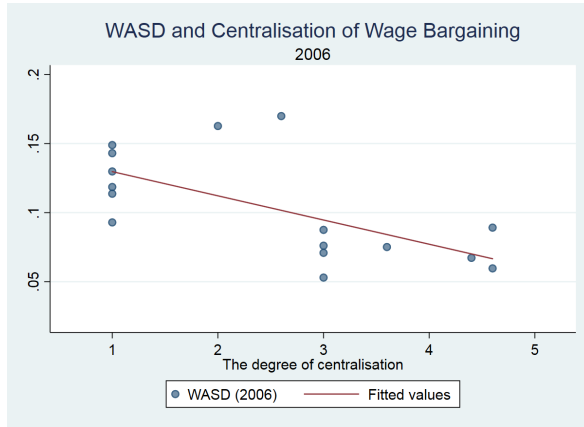


(b) WASD and Coordination

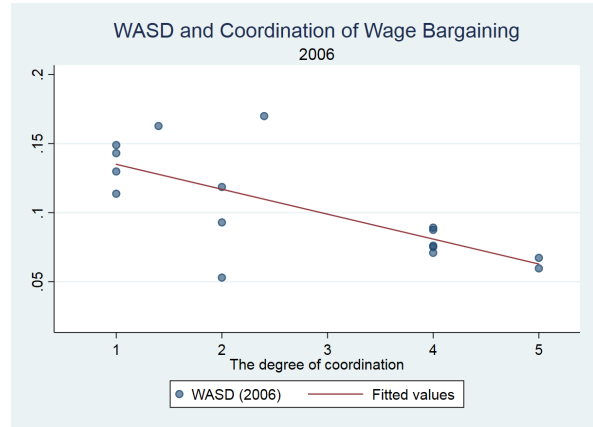


(c) WASD and Collective Bargaining Coverage

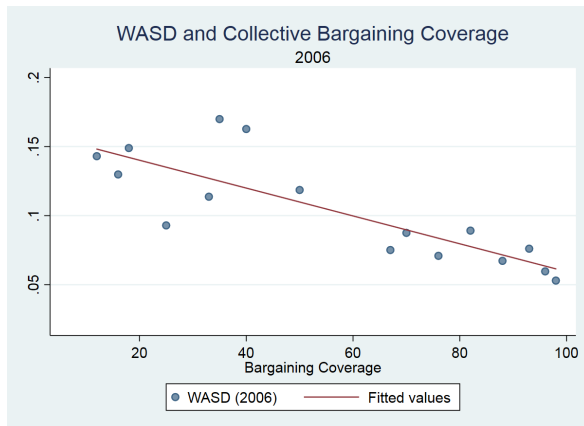
Figure 1.2: WASD and Wage Setting Institutions (2010)



(a) WASD and Centralisation



(b) WASD and Coordination



(c) WASD and Collective Bargaining Coverage

Figure 1.3: WASD and Wage Setting Institutions (2006)

Chapter 2

It's the Sectors, not the Firms: Accounting for Earnings and Wage Inequality Trends in Italy 1985-2018

Note: *This chapter is based on my work with my supervisors, Cristina Tealdi and José V. Rodríguez Mora who agreed that the essay can appear within this thesis, and that it represents a substantial contribution on my part. In particular, I carried out all of the empirical work, coding, analysis of the results and writing of the paper. Prof Tealdi and Prof Mora provided guidance and direction for the project and were instrumental in securing access to the data.*

2.1 Introduction and Related Literature

There has been a substantial increase in pay inequality in many industrialized economies since 1980s (Atkinson, Piketty, and Saez (2011)). The majority of explanations have tended to focus on market-level changes in returns to different skills and on the role that technology has played in shaping these trends (Katz and Autor (1999), Acemoglu and Autor (2011)). This has been influenced by the assumption of competitive labour markets where the rule of one price applies and thus a worker of a certain type is paid the same wage irrespective of her employer. However, there is a long literature in labour economics showing that some employers pay substantially higher wages than others for workers with the same observable skills performing similar jobs (Dickens (1987), Krueger and Summers (1988)). Furthermore,

it has been established that firm productivity varies massively within very narrowly-defined industries (Syverson (2011)). It is therefore natural to ask whether some of these productivity differences spill over to wages. A number of studies have found that trends in aggregate wage dispersion closely follow trends in the dispersion of productivity across employers (Barth, Bryson, et al. (2016)).

The availability of matched employee-employer longitudinal data, typically coming from social-security or tax records, combined with the reasons above, has led to an explosion of interest in the role that firms play in shaping cross-sectional distribution of earnings as well as its changes over time. One strand of literature focuses on estimating rent-sharing elasticity, that is elasticity of earnings of incumbent workers with respect to changes in the firm's value added (Card, Cardoso, et al. (2018), Lamadon, Mogstad, and Setzler (2019)). Another set of studies use information on earnings of workers switching between firms to decompose the cross-sectional variance of earnings into the contribution of worker heterogeneity, firm heterogeneity and sorting of workers into firms (Abowd, Kramarz, and Margolis (1999), Card, Heining, and Kline (2013)).

Another approach is to decompose the log variance of earnings into the between-firm and the within-firm variance and to track these components over time. Song et al. (2019) use a longitudinal data set covering workers and firms for the entire U.S. labor market from 1981 to 2013. They find that the between-firm variance of earnings accounts for two thirds of the rise in total variance of earnings, with the within-firm variance accounting for one third. The result that the majority of the increase in pay inequality is accounted for by increasing variance of average pay across firms is also found by Faggio, Salvanes, and Reenen (2010) for the UK and Card, Heining, and Kline (2013) for West Germany. Alvarez et al. (2018) document a decline in earnings inequality in Brazil and find that a decrease in between-firm variance of earnings accounts for the majority of the fall in overall inequality. Hence there seems to be a general trend where either a rise or a fall in overall pay inequality is driven by the between-firm component.

We contribute to this literature by using a social-security administrative data set covering the universe of private-sector employment in Italy to decompose the total variance of log annual earnings into the between-firm and the within-firm component for every year from 1985 to 2018. This is the first study to do such variance decomposition for Italy. The total variance of log annual earnings rose from 0.486 in 1984 to 0.723 in 2018. We find that 61.77% of the rise in earnings inequality occurred between firms, with the remaining 38.23% taking place within firms. This is very similar to the findings of Song et al. (2019) for the USA. Furthermore, just as in the US, the result that the majority of the earnings dispersion increase occurred between firms holds for all firm size categories. We also find that the dispersion of average earnings across firms increased as a share of total variance from 44.98% in 1985 to 50.49% in 2018. Additionally, we investigate the association of the between-firm variance share and total variance of earnings across Italian provinces and within provinces over time. Firstly, we find that the provinces where the between-firm variance represents a greater share of the total variance tend to have a larger total variance of earnings. Secondly, we find that provinces where the total earnings dispersion became larger generally experienced an increase in the share of the earnings variance accounted for by the between-firm component. On the other hand, provinces where earnings inequality declined generally had a falling between-firm share.

In contrast to other studies in the literature, the data set that we use includes not only information on earnings, but also on the quantity of labour supplied by workers. For each employment relationship in each year we have information on the number of weeks worked and on whether the employment was full-time or not. Therefore we can study the contribution of firms to wage inequality in Italy. We perform the between vs within-firm variance decomposition using the weekly wages of full-time workers for every year from 1985 to 2018. We find that total variance of log weekly wages rose from 0.240 in 1985 to 0.447 in 2018 and that the rise in the between-firm variance represented 83.84% of the overall increase in wage inequality. Thus the between-firm variance is an even more important

component of the rise in wage inequality than the rise in earnings inequality in Italy. The dispersion of average wages across firms represented 48.85% of the total wage dispersion in 1985, but that rose to 65.03% by 2018. The between-firm component accounts for the majority of the growth in wage inequality for all firm size categories and there is again a positive association of the between-firm share and total variance across provinces in Italy as well as within provinces over time.

Next we show that the between-firm variance is actually composed of two parts: the dispersion of average earnings (or wages) across sectors (between-sector variance) and the dispersion of average earnings (or wages) across firms within the same sector (between-firm-within-sector variance). Thus total variance is composed of between-sector variance, between-firm-within-sector variance and within-firm variance. We calculate the separate contribution of each factor to the overall growth of earnings and wage inequality in Italy. First, we do between vs within sector variance decomposition of both earnings and wage variance in Italy for every year from 1985 until 2018. We find that 41.59% of the rise in earnings inequality in Italy occurred between (4-digit) sectors while 58.41% took place within sectors. We find very similar numbers for wage inequality. However, a careful inspection of the results in Song et al. (2019) reveals that only 3.09% of the increase in total variance of earnings in the USA between 1981 and 2013 took place between (4 digit) sectors. Therefore rising dispersion of average earnings across sectors is a much more important component of the total earnings inequality increase in Italy than in the USA. The between-sector variance as a share of total variance declined in the USA from 20.71% in 1981 to 16.67% in 2013. Thus the importance of sector in accounting for earnings dispersion actually fell in the USA. This is in contrast to Italy where the share increased significantly, from 22.94% in 1985 to 29.06% in 2018.

Second, we identify the separate contribution of the between-firm-within-sector variance to total variance by controlling for the sector of the firm (either by sector fixed effects or by demeaning) and then performing the between vs within firm variance decomposition. We

find that the rise of the between-firm-within-sector variance accounts for 20.17% of the total increase in earnings dispersion in Italy between 1985 and 2018, the rise of the within-firm variance accounts for 38.23% and as stated above, the growth of the between-sector variance accounts for 41.59%. Therefore in Italy the dominant driver of the rising earnings inequality is the increasing dispersion of average earnings across sectors, whereas the rising dispersion of average earnings across firms in the same sector plays only a small part. This is very different from the USA where the dominant driver of the rising earnings dispersion is the between-firm-within-sector component. Song et al. (2019) find that the between-firm-within-sector variance accounts for 65.98% of the total rise in earnings variance in the USA between 1981 and 2013, the within-firm variance accounts for 30.93% and as mentioned above, the between-sector variance accounts for just 3.09%. Also the work of Faggio, Salvanes, and Reenen (2010) for the UK and Alvarez et al. (2018) for Brazil shows the dominant role of the between-firm-within-sector component in driving changes in the overall earnings dispersion.

The most likely explanation for the different patterns of rising earnings inequality between Italy and the USA are differences in wage-setting institutions. Wage bargaining in the US is at the firm level whereas in Italy it is at the level of the sector. In Italy industry-level country-wide collective agreements specify obligatory minimum wages for each occupation or job title ("livelli di inquadramento"). These occupation and sector-specific wage floors are the result of bargaining between sector-level unions and employer organisations (Boeri, Ichino, et al. (2019)). All workers in the industry irrespective of the union membership status are covered by the industry's collective agreement (Devicienti, Fanfani, and Maida (2019)). Over 90% of workers in Italy are covered by some kind of collective agreement (Visser (2016)). There are no opt-out clauses, a firm facing low demand or reduced profitability cannot reach a firm-level agreement with its workforce that would undercut the centrally negotiated terms (Fanfani (2019)). Therefore firms in Italy have very limited flexibility in wage setting. Devicienti, Fanfani, and Maida (2019) use a data set that contains information on worker wages as well as collective bargaining agreements for the region of Veneto. They show that

from the mid-1980s until the early 2000s the growth in wage dispersion in the Veneto region occurred entirely between the "livelli di inquadramento". There was no growth in wage dispersion within job titles.

This does not necessarily mean an increase in sector-specific pay premiums, some sectors paying higher wages for the workers with the same skills performing the same occupations. As Devicienti, Fanfani, and Maida (2019) argue, this suggests that the underlying market forces driving growth in pay dispersion have been directed by the centralized system of wage setting. Skill-biased technological change increases the relative demand for high skilled workers. It seems quite likely that the sector-level negotiators simply allowed these market forces to be reflected in the minimum wages for different occupations. Sectors differ in the mix of occupations that they employ, some being more skill-intensive. Therefore a rise in pay differences between workers of different skill levels could have resulted in a growing dispersion of average earnings and wages across sectors that we observe in the data. The firm-level wage bargaining in the USA is likely to lead to a stronger link between firm productivity and worker pay than in Italy. This can explain why the between-firm-within-sector variance is a larger component of the increase in total earnings variance in the US than in Italy.

Finally, we investigate the role of sector-level collective wage bargaining in driving the growth of Italian earnings and wage inequality. The ideal approach would be to calculate how much of the increase in inequality took place between vs within job titles. This is because a good measure of wage inequality that takes place outside of the collective bargaining system is the size of the wage dispersion among workers in jobs that have the same associated wage floor (within job title wage variance). Unfortunately, the Italian social-security database does not contain information on the job title (or the associated minimum wage) of employment contracts. However, it does contain a unique identifier for each collective agreement. Therefore we decompose the total variance of log weekly wages of full-time employees into the between and the within collective agreement components. The growth in the between-collective-agreement variance accounts for 29.75% of the total increase in wage

inequality in Italy between 1985 and 2018. Furthermore, if the dispersion of minimum wages for different occupations inside of each collective agreement grew over time then also some of the within-collective-agreement variance can actually be accounted for by the collective bargaining system (in a descriptive sense). Finally, based on the evidence presented here and on the results of Devicienti, Fanfani, and Maida (2019), it seems that the centralised collective bargaining system is an important factor in shaping trends in wage inequality in Italy, but due to data limitations it is not possible to precisely quantify its importance at the national level.

2.2 Data

We use a matched employer-employee administrative data set by INPS¹ which contains the universe of Italian social security records for private-sector employees. The records include employment relationships between 1975 and 2018. We focus on the period 1985-2018, as it is the period of rise of wage inequality in Italy. Given that the information is collected for the purpose of paying social security contributions, the reporting is likely very accurate. The data includes information on labour earnings (no upper limit), the number of weeks worked, unique worker and firm identifiers, location of the firm, whether the contract is full-time and on gender and year of birth of the worker. Uniquely, the database also includes information on sector of the worker. If a firm operates in multiple sectors e.g. a car company that produces cars (manufacturing) and also sells them to customers (retail), then it receives multiple identifiers from the social security institute, one for each sector that it engages in. Social security contributions of workers are registered under this sector-specific firm identifier and thus the sector of economic activity of each worker is known. In contrast administrative data from other countries typically only includes the primary sector of the firm. To ensure comparability with other studies we calculate the primary sector of a firm as the one that most of the firm’s workers belong to.

¹Istituto Nazionale della Previdenza Sociale, National Institute for Social Insurance

In this paper we aim to investigate the drivers of the growth in pay inequality in Italy and to compare them with other countries, especially the USA. The other papers in the literature, Song et al. (2019), Faggio, Salvanes, and Reenen (2010) and Alvarez et al. (2018), undertake variance decomposition of annual earnings. This is because their data does not contain information on the quantity of labour supplied by workers. In contrast, we know for each employment contract in each year how many weeks an individual worked and whether the employment was full-time or part-time. Hence we can study inequality of wage rates, in addition to inequality of earnings. We employ two different samples, one with annual earnings and one with weekly wages of full-time workers.

The annual earnings sample is drawn to be maximally comparable to Song et al. (2019). We follow their approach and sum income across all employment spells in a given year for each worker. The worker is linked with the firm that accounts for the largest share of his income. The papers that study inequality with annual earnings always impose some threshold level of annual earnings where all the observations below it are dropped. The purpose of this is to ensure that the estimates are not influenced by individuals who are not strongly attached to the labour market (e.g. someone working only for 2 weeks in a given year and thus having extremely small annual earnings). The level of this cutoff is quite arbitrary and varies across studies. Song et al. (2019) define this threshold level of earnings as the value of working full-time for one quarter for the minimum wage². Unfortunately, Italy does not have a statutory national minimum wage. Instead we drop the observations that are below 5th percentile in every year. This ensures that the total variance of annual earnings is not inflated by a few extremely small values. Following Song et al. (2019) we restrict the sample to only individuals between the age of 20 and 60. Additionally, we restrict the sample to only firms (and workers in firms) with at least 10 workers (at least 10 observations per firm)³. This is to ensure that there are enough observations to calculate within-firm variance.

²Their results are robust to varying the level of the threshold.

³Song et al. (2019) use a higher cutoff of 20 workers per firm. However, Italy has an extremely high percentage of workers employed in small firms and thus we use a lower cutoff.

The weekly wages sample is drawn to enable study of wage inequality in Italy. In the INPS data set every observation is one employment contract in a given year. A firm-worker pair might have multiple employment contracts in a given year. First, for each firm-worker match we sum all income, as well as the number of weeks worked, across employment contracts in a given year. Next, for each match we divide the total income by the total number of weeks to obtain the weekly wage. For this sample we restrict the selection to only full-time workers aged 20 to 60 and to firms and workers in firms with at least 10 such workers.

We can see from Table 2.1 that the original INPS data set (the entire universe) contains about 640,000 unique firms and approx 6.9 million unique workers in 1985 and 1.4 million firms and 14.8 million workers in 2018. The rise in the number of employed workers is mainly due to higher employment rate of women as well as population growth and immigration. The earnings sample contains approx 90,000 firms and 4.7 million workers in 1985 and approx 200,000 firms and 9.9 million workers in 2018. The weekly wages sample has about 100,000 firms and 5 million workers in 1985 and 170,000 firms and 7.8 million workers in 2018. Hence the sample restrictions that we make, especially the requirement of at least 10 workers per firm, mean that we only keep about 15% of the total number of firms. However, in terms of employment the two samples are still very large, keeping about 67% of the total number of workers.

Table 2.2 presents a comparison of firm size distribution in the universe of social-security data, earnings sample and weekly wages sample for 1985 and 2018. Unsurprisingly, firms are on average much larger in the two samples due to a higher minimum level. The median number of workers per firm in 2018 is 3 in the universe, 16 in the earnings sample and 18 in the weekly wages sample. The mean firm size in 2018 is 10.02 in the original data, 46.72 in earnings distribution and 50.07 in the weekly wages distribution.

Furthermore, the mean annual earnings are slightly higher in the earnings sample than in the original data set (Table 2.3). This is again unsurprising given that we drop the 5% lowest observations of annual earnings. The mean weekly wages are also slightly higher in

the wages sample than in the universe of social-security records (Table 2.4). This is most likely because full-time workers tend to earn higher wages on average.

Finally there has been a very large rise in both earnings and wage inequality in Italy between 1985 and 2018, as can be seen from Table 2.5. Variance of log annual earnings rose from 0.486 in 1985 to 0.723 in 2018, representing 49% increase. Variance of log weekly wages of full-time employees rose even more, from 0.240 in 1985 to 0.447 in 2018 which represents 86% increase.

2.3 Methodology

We study the role of firms in accounting for both earnings and wage inequality in Italy between 1985 and 2018. Hence we perform the following variance decomposition for both annual earnings and weekly wages of full-time employees. We decompose the total variance of log annual earnings (log weekly wages) in a given year into two components: between-firm and within-firm variance:

$$\underbrace{\frac{1}{N} \sum_{\forall i} (w_{ij} - \bar{w})^2}_{\text{total variance}} = \underbrace{\sum_{\forall j} \frac{n_j}{N} (\bar{w}_j - \bar{w})^2}_{\text{between-firm variance}} + \underbrace{\sum_{\forall j} \frac{n_j}{N} \frac{\sum_{\forall i|i \in j} (w_{ij} - \bar{w}_j)^2}{n_j}}_{\text{within-firm variance}} \quad (2.1)$$

where w_{ij} denotes the log annual earnings (log weekly wage) of worker i at firm j in a given year, N denotes the total number of workers (firm-worker matches) in the data, n_j is the number of workers employed at firm j , $\bar{w}_j = \frac{1}{n_j} \sum_{\forall i|i \in j} w_{ij}$ is the value of average annual earnings (average weekly wage) at firm j and $\bar{w} = \frac{1}{N} \sum_{\forall i} w_{ij}$ is the economy-wide value of average annual earnings (average weekly wage).

Additionally, we decompose total variance of annual earnings (weekly wages) into between-sector variance and within-sector variance:

$$\underbrace{\frac{1}{N} \sum_{\forall i} (w_{is} - \bar{w})^2}_{\text{total variance}} = \underbrace{\sum_{\forall j} \frac{n_s}{N} (\bar{w}_s - \bar{w})^2}_{\text{between-sector variance}} + \underbrace{\sum_{\forall j} \frac{n_s}{N} \frac{\sum_{\forall i|i \in s} (w_{is} - \bar{w}_s)^2}{n_s}}_{\text{within-sector variance}} \quad (2.2)$$

where w_{is} denotes the log annual earnings (log weekly wage) of a worker i in sector s in a given year, n_s is the number of workers employed in sector s and \bar{w}_s gives the average annual earnings (average weekly wage) of sector s .

Next, we want to investigate separately the contribution of sector and of the firms within the sector to the rise in earnings and wage inequality in Italy. Thus we want to first control for the sector and then undertake between vs within firm variance decomposition. There are two equivalent ways of doing this.

The first method is to regress the dependent variable (log annual earnings or log weekly wages) on sector fixed effects, so including a dummy variable for every sector and dropping the constant.

$$w_{ijs} = \sum_{s=1}^{s=S} \beta_s D_s + \epsilon_{ijs} \quad (2.3)$$

where w_{ijs} denotes the log annual earnings (log weekly wage) of a worker i in firm j in sector s in a given year, S is the total number of sectors in the data, D_s is a dummy variable that takes value 1 if the observation is for sector s and 0 otherwise, β_s is the OLS coefficient on the fixed effect for sector s , and ϵ_{ijs} is the residual.

Next we take the residuals from the above regression and perform the between vs within firm variance decomposition with them.

$$\underbrace{\frac{1}{N} \sum_{\forall i} (\epsilon_{ij} - \bar{\epsilon})^2}_{\text{within-sector variance}} = \underbrace{\sum_{\forall j} \frac{n_j}{N} (\bar{\epsilon}_j - \bar{\epsilon})^2}_{\text{between-firm-within-sector variance}} + \underbrace{\sum_{\forall j} \frac{n_j}{N} \frac{\sum_{\forall i|i \in j} (\epsilon_{ij} - \bar{\epsilon}_j)^2}{n_j}}_{\text{within-firm variance}} \quad (2.4)$$

where ϵ_{ij} is the residual from (2.3) for worker i in firm j , N still denotes the total number of workers (firm-worker matches) in the data, n_j is the number of workers employed at firm

j , $\bar{\epsilon}_j = \frac{1}{n_j} \sum_{\forall i|i \in j} \epsilon_{ij}$ is the firm j 's average value of either log annual earnings or log weekly wages after controlling for sector fixed effects and $\bar{\epsilon} = \frac{1}{N} \sum_{\forall i} \epsilon_{ij}$ is the economy-wide average of either log annual earnings or log weekly wages after controlling for sector fixed effects.

The total variance of residuals from (2.3) is equal to the within-sector variance given that controlling for sector fixed effects removes the between sector variance. Performing between vs within firm variance decomposition on the residuals from (2.3) then actually produces between-firms-within sector variance and within-firm variance.

The second method of controlling for sector is to demean each observation by the sector of the worker i.e. for every observation subtract the average of the sector that the observation belongs to. This method also removes the between-sector variance and it is equivalent to (2.3). The demeaned observations are then used to calculate (2.4).

In addition to the two methods above it is also possible to perform the full variance decomposition directly where total variance is broken down into between-sector variance, between-firms-within-sector variance and within-firm variance. This is done by combining (2.1) and (2.2):

$$\begin{aligned}
\underbrace{\frac{1}{N} \sum_{\forall i} (w_{ijs} - \bar{w})^2}_{\text{total variance}} &= \underbrace{\sum_{\forall j} \frac{n_s}{N} (\bar{w}_s - \bar{w})^2}_{\text{between-sector variance}} + \underbrace{\sum_{\forall s} \frac{n_s}{N} \sum_{\forall j|j \in s} \frac{n_j}{n_s} (\bar{w}_j - \bar{w}_s)^2}_{\text{between-firm-within-sector variance}} \\
&+ \underbrace{\sum_{\forall j} \frac{n_j}{N} \frac{\sum_{\forall i|i \in j} (w_{ijs} - \bar{w}_j)^2}{n_j}}_{\text{within-firm variance}}
\end{aligned} \tag{2.5}$$

In conclusion, all three methods above generate the same outcomes and are equivalent. We use the demeaning method which is the most convenient and is the one that Song et al. (2019) use.

2.4 Results

In this section we review the results of variance decompositions that shed light on the importance of firms as drivers of pay inequality in Italy. First, we use log annual earnings as a measure of inequality and we investigate how much of the rise in inequality between 1985 and 2018 is a between-firm phenomena (section 2.4.1). Then we consider how much of the rise in earnings inequality occurred between sectors as opposed to within sectors (section 2.4.2). In section 2.4.3 we undertake all of the analysis again, but with weekly wages of full-time workers instead of earnings. Thus we study the role of firms and sectors in accounting for wage inequality growth in Italy. In section 2.4.4 we contrast our results with annual earnings with the findings of Song et al. (2019) for the USA (who also use annual earnings). In section 2.4.5 we discuss some potential explanations for the very different results. Finally, in section 2.4.6 we investigate how much of earnings and wage inequality in Italy between 1985 and 2018 occurred between vs within collective agreements.

2.4.1 Between vs within firm variance

We perform the between vs within-firm variance decomposition given by (2.1) using the annual earnings sample for every year from 1985 until 2018. We find that the majority (61.77%) of the rise in earnings inequality in Italy occurred between firms.

We can see from Table 2.6(a) that total variance of log annual earnings rose from 0.486 in 1985 to 0.723 in 2018 and that the rise in between-firm variance represented 61.77% of the overall increase in inequality. Within-firm variance also increased and it contributed 38.23% of the increase in total variance. Furthermore, the between-firm variance also became a larger relative component of the total variance of log annual earnings (Table 2.6(b)). The dispersion in average earnings across firms represented 44.98% of the total variance in 1985, but that rose to 50.49% in 2018. Earnings inequality within firms rose over time, but at a slower rate than between firms and thus the within-firm share of total variance fell from

55.02% to 49.51%. We can also see these patterns on Figure 2.1.

Furthermore, these same patterns hold up for all firm size categories. The between-firm component of variance accounts for 65.04% of the rise in total variance for small firms, 69.50% for medium-sized firms and 58.88% for large firms (Table 2.7)⁴. We can see from Figure 2.2 that the between-firm variance grows at a faster rate than the within-firm component for firms of all sizes.

In addition to exploring the relationship between firms and earnings inequality in Italy over time we also investigate the nature of this relationship across Italian regions. Therefore we perform the between vs within firm variance decomposition given by (2.1) for every province in every year in Italy (there are just over 100 provinces). Thus we obtain between-firm variance, within-firm variance and total variance of log annual earnings for every province-year pair. This results in a panel data set of just over 3000 observations. Next we calculate the between-firm share for every province-year observation by dividing the between-firm variance by the total variance.

For each year we correlate the between-firm share with the total variance across provinces. Figure 2.3(a) shows how the correlation coefficient evolves over time. We can see that the correlation coefficient is always positive and very large. It varies between 0.7 and 0.9. This shows that provinces where the dispersion of average earnings across firms represents a greater share of total earnings dispersion tend to have larger earnings inequality.

Next, we assess the relationship of the between-firm share with total inequality in a different way. First, we regress total variance of log annual earnings for each province-year pair on year fixed effects. This way we are controlling for time trends and focusing on the variation across geography. Figure 2.3(b) displays a scatter plot of the resulting residuals and the between firm share, as well as the line of best fit. We can see that there is a clear positive relationship where province-year pairs with larger residuals (total variance of log annual earnings after controlling for year fixed effects) tend to have larger between-firm

⁴The definitions of firm size categories come from OECD and are: small firm: 10-49 employees; medium-sized firm: 50-249 employees; large firm: over 250 employees.

share. This is confirmed by a regression of the residuals on the between-firm variance share which delivers an OLS coefficient of 0.009. This means that a one percentage point rise in the between-firm share of a province is associated with the total variance of log annual earnings of the province rising by 0.009, controlling for year fixed effects. Therefore we find that there is a robust positive association between the share of the earnings inequality that occurs between firms and the overall earnings inequality across regions in Italy.

We also examine the association of the between-firm share with the total variance within provinces over time. The first way that we do this is to regress total variance of log annual earnings for each province-year pair on province fixed effects. The residuals from this regression contain only the within-province variation as the between-province variation is captured by the fixed effects. Figure 2.3(c) displays a scatter plot of these new residuals and the between firm share. There is again a clear positive relationship, province-year pairs with larger residuals (total variance of log annual earnings after controlling for province fixed effects) tend to have larger between-firm share. Regression of these residuals on the between-firm variance share delivers an OLS coefficient of 0.0027. Therefore we find that a rise in the between-firm share of a province over time is associated with a rise in the total variance of log annual earnings of that province.

Finally, for each province we calculate the change in the between-firm share and in the total variance over time (between 1985 and 2018) and we plot them in Figure 2.3(d). We can see that provinces where the total earnings dispersion became larger generally experienced an increase in the share of the earnings variance accounted for by the between-firm component. On the other hand, provinces where earnings inequality declined generally had a falling between-firm share. This demonstrates that the positive association of the between-firm share with the total variance over time holds not only on the level of the whole country, but also within provinces.

2.4.2 Between vs within sector variance

We perform the between vs within sector variance decomposition given by (2.2) using the annual earnings sample for every year from 1985 until 2018. We find that 41.59% of the rise in earnings inequality in Italy occurred between (4-digit) sectors while 58.41% took place within sectors⁵. Therefore the rising dispersion of average earnings across sectors plays a very important role in accounting for the growth of earnings inequality in Italy.

We can see from Table 2.8(a) that the between-sector variance rose from 0.111 in 1985 to 0.210 in 2018, accounting for 41.59% of the rise in total variance. The within-sector variance increased from 0.374 to 0.513, representing 58.41% of the overall rise of variance of log annual earnings. Furthermore, Table 2.8(b) shows that the dispersion of average earnings across sectors became a larger share of the total dispersion of earnings over time. The between-sector variance share was 22.94% in 1985 and 29.06% in 2018. The within-sector share declined from 77.06% to 70.94% in the same time period. While both types of earnings dispersion were rising over time, the between-sector variance was rising faster and thus became a larger relative component of earnings inequality. We can see these patterns on Figure 2.4.

Next, we investigate the nature of the relationship between sectors and earnings inequality across Italian regions. We perform the between vs within sector variance decomposition given by (2.2) for every province in every year. Thus we obtain between-sector variance, within-sector variance and total variance of log annual earnings for every province-year pair. We calculate the between-sector share for every province-year observation by dividing the between-sector variance by the total variance.

We assess the relationship of the between-sector share with total inequality across Italian provinces in two different ways. First, we correlate the between-sector share with the total variance across provinces for each year. We can see from Figure 2.5(a) that the correlation coefficient is always positive and very large. It varies between 0.6 and 0.85. This shows that

⁵There are approx 600 sectors at 4-digit level in the data.

the provinces where the dispersion of average earnings across sectors represents a greater share of total earnings dispersion tend to have larger earnings inequality.

Second, as in the section 2.4.1, we regress total variance of log annual earnings for each province-year pair on year fixed effects. This way we are controlling for time trends and focusing on the variation across geography. Figure 2.5(b) displays a scatter plot of the resulting residuals and the between-sector share, as well as the line of best fit. We can see that there is a clear positive relationship where province-year pairs with larger residuals (total variance of log annual earnings after controlling for year fixed effects) tend to have larger between-sector variance share. A regression of the residuals on the between-sector share delivers an OLS coefficient of 0.0089. Thus a one percentage point rise in the between-sector share of a province is associated with the total variance of log annual earnings of the province rising by 0.0089, after controlling for year fixed effects. To sum up, we find that there is a robust positive association between the share of the earnings inequality that occurs between sectors and the overall earnings inequality across regions in Italy.

Following this, we explore the association of the between-sector share with the total variance within provinces over time. We run two different exercises. First, we regress total variance of log annual earnings for each province-year pair on province fixed effects. The residuals from this regression represent the within-province variation in the dependent variable, as the between-province variation is captured by the fixed effects. Figure 2.5(c) displays a scatter plot of these new residuals and the between-sector share. The relationship is positive, the province-year pairs with larger residuals (total variance of log annual earnings after controlling for province fixed effects) tend to have larger between-sector share. Regression of these residuals on the between-sector variance share produces a coefficient of 0.0019. Hence we find that a rise in the between-sector share of a province over time is associated with a rise in the total variance of log annual earnings of that province.

Finally, for each province we calculate the change in the between-sector share and in the total variance between 1985 and 2018 and we plot them in Figure 2.5(d). We can see

that provinces where the total earnings dispersion became larger generally experienced an increase in the share of the earnings variance that occurs between sectors. On the other hand, provinces where earnings inequality declined generally had a falling between-sector share. To sum up, we find that the positive association of the between-sector share with the total variance over time holds not only at the level of the whole country, but also within provinces. This is in addition to the fact that the relationship holds across geography.

Next, we want to investigate separately the contribution of sector and of the firms within the sector to the rise in earnings inequality in Italy. Therefore we control for the sector as explained in the Methodology section (2.3). Table 2.9(a) and Figure 2.6(a) show the results of the between vs within firm variance decomposition applied to the data after controlling for the primary sector of the firm. In this case the growth of the between-firm variance contributed 34.54% of total variance increase while the growth of the within-firm variance contributed 65.46% of the total increase. Therefore once we control for the sector that the firm belongs to, most of the earnings increase is due to rising inequality within firms, not between firms within sector. Given that we are controlling for the sector of the firm, the between-firm variance here is actually the between-firm-within-sector variance and the total variance is equal to the within-sector variance. The within-firm variance is unaffected by whether we control for the sector or not.

In section 2.4.1 we find that the majority (62%) of the rise in earnings inequality in Italy between 1985 and 2018 took place between firms. In this section we show that the between-firm variance is actually composed of two parts: between-sector variance and between-firm-within-sector variance⁶. Table 2.10(a) shows the full variance decomposition over time. We can see that the growth of the between-sector variance accounts for 41.59% of the total variance increase, the rise of the between-firm-within-sector variance accounts for 20.17% and the rise of the within-firm variance accounts for 38.23%. Thus the most important factor is the rising dispersion of average earnings across sectors. Figure 2.6(b) shows that all

⁶Also within-sector variance is composed of two parts: between-firm-within-sector variance and within-firm variance.

three types of earnings dispersion were growing over this time period. However, we can see from Table 2.10(b) that while the between-sector component grew as a share of total variance from 22.94% in 1985 to 29.06% in 2018, the shares of both the between-firm-within-sector and the within-firm components fell during this period.

Additionally, we also exploit a unique aspect of the Italian social-security data which is that the sector of economic activity is measured at the level of the individual worker. In the analysis above we were using the primary sector of the firm which is the economic activity that the largest group of the firm's workers are engaged in. Now we control for the sector of the worker. Thus if a firm operates in multiple sectors then for the purpose of this analysis it is effectively broken up into the different sector-specific parts. Table 2.11 displays the results of the between vs within firm variance decomposition after controlling for the sector of the worker. The main finding is that the results differ only marginally from the ones where we control for the primary sector of the firm. Table 2.12 shows the full variance decomposition. The between-sector variance accounts for 42.20% of the total variance increase, the between-firm-within-sector component accounts for 19.58% and the within-firm component accounts for 38.22%. The growing dispersion of average earnings across sectors is still the main driver of the rising earnings inequality and it increases as a share of total variance while the other two components decline as shares of total variance. In conclusion, we find that controlling for the primary sector of the firm or for the sector of the worker produces almost identical results.

2.4.3 Wage inequality vs earnings inequality

In this section we compare the results of variance decomposition using log weekly wages of full-time employees with the results using log annual earnings that we discussed in sections 2.4.1 and 2.4.2.

First, we perform the between vs within-firm variance decomposition given by (2.1) using the weekly wages (of full-time workers) sample for every year from 1985 until 2018. We find

that the between firm variance is an even more important component of the rise in total wage variance than of the rise of total earnings variance. The vast majority, specifically 83.84%, of the rise in wage inequality in Italy occurred between firms (61.77% for earnings).

We can see from Table 2.13(a) that total variance of log weekly wages rose from 0.240 in 1985 to 0.447 in 2018 and that the rise in between-firm variance represented 83.84% of the overall increase in inequality. Within-firm variance also increased, but it contributed only 16.16% of the increase in total variance. Furthermore, the between-firm variance also became a larger relative component of the total variance of log weekly wages (Table 2.13(b)). The dispersion of average wages across firms represented 48.85% of the total variance in 1985, but that rose to 65.03% by 2018. Wage inequality within firms rose over time, but at a much slower rate than between firms and thus the within-firm share of total variance fell (just as in the case of annual earnings) from 51.15% to 34.97%. These patterns can also be seen on Figure 2.7.

Furthermore, as was the case for annual earnings, these same patterns hold up for all firm size categories. However, the importance of the between firm dispersion in accounting for the growth in inequality seems to be increasing in firm size. The between-firm component of variance accounts for 75.55% of the rise in total variance for small firms, 78.85% for medium-sized firms and 93.52% for large firms (Table 2.14)⁷. We can see from Figure 2.8 that the between-firm variance grows at a faster rate than the within-firm component for firms of all sizes, but particularly for large firms.

We also explore the relationship between firms and wage inequality across Italian provinces and within provinces over time. To do this we perform exactly the same analysis as for annual earnings in section 2.4.1. The outcomes are displayed in Figures 2.9(a)-2.9(d). We find broadly the same results as for annual earnings. There is a positive association between the share of the wage inequality that occurs between firms and the overall wage inequality across provinces in Italy. However, this relationship is weaker than in the case of earnings. For

⁷The definitions of firm size categories come from OECD and are: small firm: 10-49 employees; medium-sized firm: 50-249 employees; large firm: over 250 employees.

example, we can see from Figure 2.9(a) that the correlation coefficient of the between firm share and the total wage variance across provinces varies depending on the year between 0.2 and 0.8 (for annual earnings it varies between 0.7 and 0.9).

Furthermore, we find that the provinces where the total wage dispersion became larger generally experienced an increase in the share of the wage variance accounted for by the between-firm component. On the other hand, the provinces where wage inequality declined generally had a falling between-firm share. This is the same pattern as in the case of annual earnings. However, the association of the between-firm share and the total variance within provinces over time is actually stronger for wages than for earnings. For instance, we can see from Figure 2.9(d) that the correlation of the change in the between-firm share of a province between 1985 and 2018 with the change of the total variance of wages of a province over the same time period produces a coefficient of 0.76 (the correlation coefficient is 0.52 for annual earnings).

Next, we turn my attention to the importance of the differences in average wages across sectors for explaining wage inequality. We perform the between vs within sector variance decomposition given by (2.2) using the weekly wages (of full-time employees) sample for every year from 1985 until 2018. The main finding is that the importance of sectors in accounting for the growth in inequality is very similar for wages and for earnings. The rising dispersion of average wages across sectors plays a very important role in accounting for the growth of wage inequality in Italy.

We can see from Table 2.15(a) that 44.23% of the rise in wage inequality in Italy occurred between (4-digit) sectors while 55.77% took place within sectors (for earnings it was 41.59% vs 58.41% split). Furthermore, Table 2.15(b) shows that the dispersion of average wages across sectors became a larger share of the total wage dispersion over time. While both the between and the within sector wage variance were rising over time, the between-sector variance was rising faster and thus became a larger relative component of wage inequality. This is the same as for earnings. We can see these patterns on Figure 2.10.

Next, we investigate the nature of the relationship between the share of wage variance that takes place between sectors and the total wage variance across Italian provinces and within each province over time. We repeat the same analysis as for annual earnings in section 2.4.2. The results are shown in Figures 2.11(a)-2.11(d). We find that there is a positive association between the share of the wage inequality that occurs between sectors and the overall wage inequality across provinces in Italy. This is the same result as for annual earnings. Additionally, we find that just as in the case of annual earnings, a rise in the between-sector variance share of a province over time is associated with a rise in the total variance (of log weekly wages of full-time employees) of that province.

We continue by investigating the separate contribution of sector and of the firms within the sector to the rise of wage inequality in Italy. Therefore we control for the sector of the firm as explained in the Methodology section. Table 2.16(a) and Figure 2.12(a) show the results of the between vs within firm variance decomposition applied to the data after controlling for the primary sector of the firm. The results are very different to the ones for annual earnings. About two thirds of the rise in total wage variance between 1985 and 2018 after controlling for the main sector of the firm occurred between firms, with the remaining one third occurring within firms. For the annual earnings it was approximately one third between firms and two thirds within firms.

Given that we are controlling for the sector of the firm, the between-firm variance here is actually the between-firm-within-sector variance and the total variance is equal to the within-sector variance (as discussed in detail in the Methodology section). The within-firm variance is unaffected by whether we control for the sector or not. Table 2.17(a) shows the full variance decomposition over time. We can see that the most important driver of rising inequality is still the between-sector component accounting for 44.23% of the overall increase (very similar to the case of annual earnings). The rise of the between-firm-within-sector variance accounts for 39.60% of the overall increase and the rise of the within-firm variance accounts for 16.16% of the total wage variance increase. We can see that compared to the

variance decomposition of annual earnings, the between-firm-within-sector variance plays a much more important role and the within-firm variance is less important in accounting for the overall rise in inequality. A likely reason why the within-firm variance is a more important component of the growth of earnings inequality than the growth of wage inequality is the existence of short-term contracts which were much more common in 2018 than they were in 1985. A rising prevalence of short-term employment likely increased variance of earnings within firms because it expanded the differences in the number of weeks worked among the workers at the same firm. Variance of wages within firms was less affected by the increasing prevalence of short-term employment because the differences in wages between the firm's permanent and temporary workers are likely to be much smaller than the differences in labour supply. Figure 2.12(b) shows that all three types of wage dispersion were growing over this time period. However, we can see from Table 2.17(b) that while the between-sector and the between-firm-within-sector components grew as a share of total variance, the share of the within-firm component fell during this period.

Additionally, we exploit the unique feature of the Italian social security data that the sector of economic activity is measured at the level of the individual worker. Thus we repeat the analysis above (controlling for sector) while using the sector of the worker instead of the primary sector of the firm. We find that the estimates change only marginally, there are no major differences. The results are displayed in Tables 2.18 and 2.19.

Finally, we summarise the main results of this section. We find that the between-firm variance is an even more important component of the rise in total variance for wage inequality than for earnings inequality. Approximately 84% of the rise in wage variance in Italy between 1985 and 2018 took place between firms. The share of the increase in total variance that took place between sectors is very similar for both wage and earnings inequality (44.23% for wages, 41.59% for earnings). In both cases the rise in the between-sector variance is the largest component of the total variance increase. However, the rise in the between-firm-within-sector variance is a much more important driver of the overall inequality increase for

wages than for earnings. On the other hand, the rise in the within-firm variance is much more important for explaining the growth of earnings inequality than for wage inequality. Finally, for both wage and earnings dispersion, there is a positive association of the between-firm variance share and the between-sector variance share on one hand, and the total variance on the other, across provinces as well as within provinces over time.

2.4.4 Comparison with the USA

In this section we compare our findings for Italy using the annual earnings sample with the results of Song et al. (2019) who use US social security data and also perform variance decomposition using annual earnings. Firstly, we quickly summarise our findings for annual earnings. We find that the rise in the between-firm variance represented 61.77% of the overall increase in earnings inequality in Italy between 1985 and 2018. Furthermore, we find that as total earnings dispersion grew, the between-firm component became a larger share of the total variance. The between-firm share grew from 44.98% in 1985 to 50.49% in 2018. We find that this positive association of the between-firm share with the total variance holds also within provinces over time. Additionally, we find that provinces where a larger share of earnings inequality takes place between firms tend to have larger overall earnings dispersion.

Considering the importance of sectors, we find that the rise in the between-sector variance represented 41.59% of the overall increase in earnings variance. We also find that the between-sector variance as a share of the total variance increased from 22.94% in 1985 to 29.06% in 2018. Furthermore, we find that, as in the case of the between-firm share, there is a robust, positive association between the share of the earnings inequality that occurs between sectors and the overall earnings inequality, both across provinces in Italy and over time within provinces. Finally, we divide the between-firm variance into two components, the between-sector variance and the between-firm-within-sector variance, and find that the dominant driver of the rising earnings dispersion in Italy is the growth in the dispersion of average earnings across sectors, and not the rise in the dispersion of average earnings across

firms within the same sector.

The results of the between vs within firm variance decomposition in Song et al. (2019) are displayed in Table 2.20⁸. The rise in the between-firm variance accounted for 69.59% of the increase in the overall earnings dispersion in the USA between 1981 and 2013, with the remaining 30.41% being accounted by the within-firm component of the total variance. Hence in this respect my results for Italy are in line with the results of Song et al. (2019) for the USA. Furthermore, Song et al. (2019) also find that the share of the total earnings inequality that occurs between firms increased. In their case the between-firm share rose from 34.05% to 42.20%.

Table 2.21 summarise the results of between vs within sector variance decomposition for the USA. The results for the USA are starkly different from our results for Italy. Only 3.09% of the increase in total variance of earnings in the USA between 1981 and 2013 was accounted for by the between-sector (4 digit) component. 96.91% of the increase in inequality there was a within-sector phenomenon. The between-sector variance share in the USA declined from 20.71% in 1981 to 16.67% in 2013. Thus the relative importance of sector actually fell in the USA. This is in contrast to Italy where the share increased significantly. We can see from Table 2.22 that the massive increase in the within-sector earnings dispersion in the USA is mainly due to increasing dispersion of earnings across firms within sector (68.09%) and to a lesser extent due to increasing dispersion in earnings within firms (31.91%). Table 2.23 shows the full sector versus firm variance decomposition for the USA. As said above, the growth in the between-sector variance accounts for just 3.09% of the rise in the total variance of log annual earnings in the USA, the between-firm-within-sector variance accounts for 65.98% and the within-firm variance accounts for 30.93%. Whereas in the US the dominant driver of the rising earnings dispersion is the between-firm-within-sector component, in Italy it is the between-sector component. There are also significant differences when looking at levels. In Italy the between-sector variance represented 29.06% of the total variance in 2018, whereas

⁸This and the other tables in this chapter summarising the results of Song et al. (2019) come from "Table 2: Robustness checks on variance decomposition" in their paper.

in the USA the between-sector variance share was just 16.67% in 2013. Therefore sector plays much more important role in Italy than in the USA in terms of both explaining the rise in earnings inequality over time and in accounting for cross-sectional distribution of earnings in recent years.

2.4.5 Possible explanations

Empirical findings in the previous section raise two questions. First, why does the rising dispersion of average earnings across sectors explain so little of the increase in inequality in the US, but so much in Italy? Second, why is the dispersion of earnings across firms within the same narrowly-defined sectors such an important component of the rising total variance of earnings in the US, but not in Italy?

The most likely explanation for the different patterns of rising earnings inequality are *differences in wage-setting institutions*. Wage bargaining in the US is at the firm level whereas in Italy it is at the level of the sector. In Italy industry-level country-wide collective agreements specify obligatory minimum wages for each occupation or job title ("livelli di inquadramento")⁹. The job titles are defined by collective bargaining agreements and are based on the complexity of the employee's tasks, qualifications and seniority levels (Fanfani (2019)). Each collective agreement specifies minimum wages for 5-10 different job titles (Fanfani (2019)). The minimum wages for each job title in each industry are the outcome of negotiations between sector-level unions and employer organisations (Boeri, Ichino, et al. (2019)). However, the mapping of collective agreements to industries is not perfect, some industries have multiple collective agreements and sometime a single collective agreement covers multiple industries (Fanfani (2019)). Over 90% of workers in Italy are covered by collective agreements (Visser (2016)). Collective agreements apply to all workers in the covered firms irrespective of the union membership status (Devicienti, Fanfani, and Maida (2019)). Additionally, there are no opting-out clauses in the Italian system of industrial relations

⁹There are hundreds of collective agreements, but approx 150 of the largest ones cover over 90% of workers in the INPS social-security data set.

(Devicienti, Fanfani, and Maida (2019)). A firm facing low demand or reduced profitability cannot reach a firm-level agreement with its workforce that would undercut the centrally negotiated terms. Furthermore, firms cannot downgrade workers to lower paid job titles, as workers can only move up in the firms' hierarchy (Fanfani (2019)). Thus firms in Italy have very limited flexibility in wage setting and as a result the relationship between wages and firm productivity and local labour market conditions is much weaker in Italy than in Germany or the USA (Boeri, Ichino, et al. (2019)).

While firms in Italy cannot pay below the wages set at the sector level, they are completely free to pay above the minimum levels specified for each occupation. The most productive firms in each industry could still pay above the standard rate in order to attract the best workers. The fact that the dispersion of earnings across firms within an industry is quite small is likely due to two factors: 1. the minimum wages are set quite high, so there is little scope to pay above them and many firms would prefer to pay below them, but cannot; 2. firms have little incentive to pay above the minimum and poach the best workers from other firms.

Devicienti, Fanfani, and Maida (2019) use a data set that contains information on worker wages as well as collective bargaining agreements for the region of Veneto. They show that from the mid-1980s until the early 2000s the growth in wage dispersion in the Veneto region occurred entirely between the "livelli di inquadramento". There was no growth in wage dispersion within job titles. It is quite likely that the pattern at national level will be quite similar¹⁰. This suggests that the growth in wage inequality in Italy has been mainly the result of the rising dispersion of occupation-specific minimum wages.

This does not necessarily imply that there was an increase in sector-specific pay premiums in Italy, i.e. some sectors paying higher wages for the workers with the same skills performing the same occupations. As Devicienti, Fanfani, and Maida (2019) argue, their result suggests that the underlying market forces driving growth in pay dispersion have been channelled by

¹⁰Although this has so far not been studied due to data limitations.

the centralized system of wage setting. Skill-biased technological change increases the relative demand for high skilled workers. It seems quite likely that the sector-level negotiators simply allowed these market forces to be reflected in the minimum wages for different occupations. Sectors differ in the mix of occupations that they employ, some being more skill-intensive. Therefore a rise in pay differences between workers of different skill levels could have resulted in a growing dispersion of average earnings across sectors that we observe in the data. If firms within narrowly-defined sectors in Italy differ much less in their occupational mix then this would explain why the between-firm-within-sector variance did not grow as much.

Furthermore, given that wage bargaining is at the firm level in the USA, there is likely a stronger link between firm productivity and worker pay in the US than in Italy. Rusinek and Rycx (2013) show that firm-level wage bargaining is associated with greater rent-sharing than centralised wage setting. In the recent decades there has been a trend in the USA of a few "superstar firms" in each industry pulling out from the rest of the firms in terms of productivity and market share (Autor et al. (2020)). It is quite likely that under firm-level wage setting this pattern spilled over into wages. This can partially explain why the between-firm-within-sector variance is such a large component of the increase in total earnings variance in the US, but not in Italy.

There is also another possible explanation of the patterns of rising earnings and wage dispersion that we identify in the Italian data and it involves a government intervention in the economy before 1985 via a policy called *Scala Mobile*. *Scala Mobile* was a wage indexation mechanism granting the same absolute wage increase to all employees as prices rose, thereby compressing wage differentials between workers of different skill types. Manacorda (2004) shows that as a result of the pay-indexation scheme there was a substantial compression of nominal wage dispersion from late 1970s until 1985 (when the policy was abandoned). It could be argued that the rise in inequality after 1985 was simply a correction for the previous policy, a return to some "normal" wage dispersion. The increase in the variance of average earnings across sectors could be driven by the fact that some sectors are more

skill-intensive than others and that the wage differential between workers of different skill level and occupation was rising back to some natural level. However, while this story can partially explain the rise in earnings inequality in the second half of 1980s and in 1990s, it cannot explain the continuing rise of pay inequality in the 2000s, many years after the policy ended. We can see from Figure 2.1 and Figure 2.7 that the total variance of log annual earnings and of log weekly wages, respectively, continued rising between 2000 and 2018.

2.4.6 Between vs within collective agreement variance

In this section we investigate the role of sector-level collective wage bargaining in driving the growth of Italian earnings and wage inequality. The ideal approach would be to calculate how much of the increase in inequality took place between vs within job titles, the occupational categories that each have an associated minimum wage. This way we could see whether the result of Devicienti, Fanfani, and Maida (2019) for the Veneto region, that all the wage inequality growth occurred between job titles, holds up at the level of the whole country. Unfortunately, the Italian social-security database does not contain information on the job title (or the associated minimum wage) of employment contracts. However, it does contain a unique identifier for each collective agreement.

Therefore we decompose the total variance of log annual earnings and of log weekly wages (of full-time employees) into between-collective-agreement variance and within-collective-agreement variance. The results for log annual earnings can be seen on Figure 2.13. The rising dispersion of average earnings across different collective agreements accounts for 42.64% of the total increase in earnings inequality between 1985 and 2018 (Table 2.24(a))¹¹. The remaining 57.36% of the growth in earnings inequality occurred among workers covered by the same collective agreement. This within-collective-agreement variance can be further broken down into two components: between-firm-within-collective-agreement variance and within-

¹¹This number is extremely close to the total increase of log annual earnings that can be accounted for by the between-sector variance (41.59%, Table 2.8(a)). However, for weekly wages the two figures are very different. This highlights the fact that the between-collective-agreement variance and the between-sector variance are not the same thing, because sectors and collective agreements do not overlap perfectly.

firm (within collective agreement) variance. The rising dispersion of average earnings across firms covered by the same collective agreement accounts for 17.90% of the overall increase and the rising dispersion of earnings within firms (within the same collective agreement) accounts for 39.45% of the increase (Table 2.25). Between-collective-agreement variance represented 21.24% of total earnings variance in 1985, but this went up to 28.27% by 2018 (Table 2.24(b)). On the other hand, the between-firm-within-collective-agreement variance and the within-firm variance fell as a share of the total variance.

The variance decomposition of log weekly wages is displayed in Figure 2.14. We can see that for weekly wages the between-collective-agreement variance is a much weaker driver of the growth of the overall variance than for annual earnings. The rising dispersion of average wages across different collective agreements accounts for 29.75% of the total increase in wage inequality in Italy between 1985 and 2018 (Table 2.26(a)). 70.25% of the growth in wage inequality occurred among workers covered by the same collective agreement. The rising dispersion of average wages across firms covered by the same collective agreement accounts for 53.15% of the overall increase and the rising dispersion of wages within firms (within the same collective agreement) accounts for 17.11% of the increase (Table 2.27). Between-collective-agreement variance share went up only very slightly from 27.61% in 1985 to 28.60% in 2018 (Table 2.26(b)). However, the between-firm-within-collective-agreement share increased dramatically from 26.55% in 1985 to 38.85% in 2018 (Table 2.27(b)). On the other hand, within-firm variance fell as a share of the total variance.

Given that sector-level collective bargaining sets wages and not earnings, it makes sense to focus on the variance decomposition of wages. An interesting question to ask is what share of the rise in wage inequality between 1985 and 2018 in Italy occurred inside vs outside of the centralised system of wage setting. A good measure of wage inequality that takes place outside of the collective bargaining system is the size of the wage dispersion among workers in jobs that have the same associated wage floor (within job title wage variance). On the other hand, the part of the wage inequality that can be accounted for by the collective

bargaining system is the wage dispersion between job titles (between units that each have a wage floor set by collective bargaining). There are multiple job titles within each collective agreement. Therefore the between-job-title variance can be further broken down into the between-collective-agreement variance and the between-job-title-within-collective-agreement variance. We are unable to measure the between-job-title-within-collective-agreement variance, but we do calculate the between-collective-agreement variance. Hence we can conclude that at least 29.75% of the total increase in wage inequality in Italy between 1985 and 2018 can be accounted for by developments inside of the centralised system of wage setting (in a descriptive sense). Furthermore, if the dispersion of minimum wages for different occupations inside of each collective agreement grew over time then also some of the within-collective-agreement variance can actually be accounted for by the collective bargaining system. Finally, based on the evidence presented here and on the results of Devicienti, Fanfani, and Maida (2019), the centralised collective bargaining system seems to be an important factor shaping trends in wage inequality in Italy, but due to data limitations it is not possible to precisely quantify its importance at national level.

2.5 Conclusion

Studies covering the USA, the UK and Brazil have found that the majority of the growth in earnings inequality in the recent decades occurred between firms as opposed to within firms. We confirm this pattern for Italy. However, we focus attention on the fact that the between firm variance is composed of two parts: the dispersion of average earnings across sectors and the dispersion of average earnings across firms within sectors. We find that the dominant driver of the growth in earnings inequality in Italy between 1985 and 2018 was the growth in the between-sector variance. In contrast, the results of Song et al. (2019) reveal that in the US the rise in the between-sector variance was only a tiny component of the increase in total earnings variance and instead the dominant factor was the growth in the between-firm-

within-sector variance. One of the explanations put forward by Song et al. (2019) for the patterns of earnings inequality increase in the US is that some universal market forces related to technology were driving increased differentiation of firms in the same narrow industries in terms of pay. These could be increased positive complementarity in production between high productivity firms and high ability workers or productivity gains from high ability workers clustering in the same firms. We demonstrate that the patterns they identify for the US are far from universal. Furthermore, we argue that the very different drivers of earnings inequality growth (in a descriptive sense) are most likely the result of the differences in wage setting institutions. Wage bargaining in the US is at the firm level whereas in Italy there is a centralised system of sector-level collective bargaining where a minimum wage is set for each occupation in each industry. This highlights the importance of cross-country differences in wage setting institutions and the role of interactions between these institutions and technological forces.

Tables

Table 2.1: Descriptive statistics

	Number of firms	Number of workers	Number of matches
entire universe 1985	643,152	6,934,287	7,291,934
earnings sample 1985	92,171	4,748,716	-
wages sample 1985	102,524	4,979,445	5,178,157
entire universe 2018	1,480,225	14,836,334	17,341,308
earnings sample 2018	211,879	9,899,139	-
wages sample 2018	173,521	7,789,788	8,688,064

Table 2.2: Firm size distribution

	mean	standard deviation	10th percentile	50th percentile	90th percentile
entire universe 1985	10.78	164.58	1	3	15
earnings sample 1985	51.52	403.97	10	18	76
wages sample 1985	50.51	404.56	10	18	75
entire universe 2018	10.02	213.71	1	3	14
earnings sample 2018	46.72	487.66	10	16	66
wages sample 2018	50.07	547.94	11	18	73

Table 2.3: Annual earnings distribution

	mean	standard deviation	10th percentile	50th percentile	90th percentile
entire universe 1985	7,582	6,163	1,278	7,456	12,838
earnings sample 1985	8,989	6,336	2,690	8,510	14,078
entire universe 2018	21,729	22,253	2,697	19,135	41,050
earnings sample 2018	25,419	23,189	5,634	22,587	45,464

Table 2.4: Weekly wages distribution

	mean	standard deviation	10th percentile	50th percentile	90th percentile
entire universe 1985	172.67	159.58	82.02	157.50	255.71
wages sample 1985	189.94	167.19	104.88	170.37	335.06
entire universe 2018	452.38	476.29	129.75	392.15	789.63
wages sample 2018	586.81	546.23	276.97	496.33	955.33

Table 2.5: The rise in earnings and wage inequality in Italy 1985-2018

	total variance	
	log annual earnings	log weekly wages
1985	0.486	0.240
2018	0.723	0.447
% increase	48.87	86.05

Table 2.6: Between vs within firm variance decomposition (Italy, annual earnings)

(a) Change over time

	between firm	within firm	total variance
1985	0.218	0.267	0.486
2018	0.365	0.358	0.723
change	0.147	0.091	0.237
% of total increase	61.77	38.23	100.00

(b) Shares

	between firm share	within firm share	total
1985	44.98	55.02	100.00
2018	50.49	49.51	100.00

Table 2.7: Between vs within firm variance decomposition for different firm sizes (Italy, annual earnings)

(a) Small firms			
	between firm	within firm	total variance
1985	0.214	0.267	0.482
2018	0.359	0.345	0.703
change	0.144	0.077	0.221
% of total increase	65.04	34.96	100.00

(b) Medium-sized firms			
	between firm	within firm	total variance
1985	0.202	0.276	0.479
2018	0.352	0.342	0.694
change	0.150	0.066	0.215
% of total increase	69.50	30.50	100.00

(c) Large firms			
	between firm	within firm	total variance
1985	0.162	0.261	0.423
2018	0.329	0.378	0.707
change	0.167	0.117	0.284
% of total increase	58.88	41.12	100.00

Small firm: 10-49 employees; medium-sized firm: 50-249 employees; large firm: over 250 employees.

Table 2.8: Between vs within sector variance decomposition (Italy, annual earnings)

(a) Change over time			
	between sector	within sector	total variance
1985	0.111	0.374	0.486
2018	0.210	0.513	0.723
change	0.099	0.139	0.237
% of total increase	41.59	58.41	100.00

(b) Shares			
	between sector share	within sector share	total
1985	22.94	77.06	100.00
2018	29.06	70.94	100.00

Table 2.9: Controlling for sector of the firm: between vs within firm variance decomposition (Italy, annual earnings)

(a) Change over time			
	between firm	within firm	total variance
1985	0.107	0.267	0.374
2018	0.155	0.358	0.513
change	0.048	0.091	0.139
% of total increase	34.54	65.46	100.00

(b) Shares			
	between firm share	within firm share	total
1985	28.61	71.39	100.00
2018	30.22	69.78	100.00

Table 2.10: Sector and firm: full variance decomposition (Italy, annual earnings)

(a) Change over time				
	between sector	between firms within sector	within firm	total variance
1985	0.111		0.107	0.267
2018	0.210		0.155	0.358
change	0.099		0.048	0.091
% of total increase	41.59		20.17	38.23

(b) Shares				
	between sector share	between firms within sector share	within firm share	total
1985	22.94		22.05	55.01
2018	29.06		21.43	49.51

Table 2.11: Controlling for sector of the worker: between vs within firm variance decomposition (Italy, annual earnings)

(a) Change over time			
	between firm	within firm	total variance
1985	0.107	0.267	0.374
2018	0.153	0.358	0.512
change	0.046	0.091	0.137
% of total increase	33.87	66.13	100.00

(b) Shares			
	between firm share	within firm share	total
1985	28.57	71.43	100.00
2018	29.99	70.01	100.00

Table 2.12: Sector of the worker and firm: full variance decomposition (Italy, annual earnings)

(a) Change over time					
	between sector	between firms	within sector	within firm	total variance
1985	0.111		0.107	0.267	0.486
2018	0.211		0.153	0.358	0.723
change	0.100		0.046	0.091	0.237
% of total increase	42.20		19.58	38.22	100.00

(b) Shares					
	between sector share	between firms	within sector share	within firm share	total
1985	22.91		22.03	55.06	100.00
2018	29.24		21.22	49.54	100.00

Table 2.13: Between vs within firm variance decomposition (Italy, weekly wages)

(a) Change over time			
	between firm	within firm	total variance
1985	0.117	0.123	0.240
2018	0.291	0.156	0.447
change	0.173	0.033	0.207
% of total increase	83.84	16.16	100.00

(b) Shares			
	between firm share	within firm share	total
1985	48.85	51.15	100.00
2018	65.03	34.97	100.00

Table 2.14: Between vs within firm variance decomposition for different firm sizes (Italy, weekly wages)

(a) Small firms			
	between firm	within firm	total variance
1985	0.098	0.088	0.185
2018	0.266	0.142	0.409
change	0.169	0.055	0.223
% of total increase	75.55	24.45	100.00

(b) Medium-sized firms			
	between firm	within firm	total variance
1985	0.111	0.114	0.225
2018	0.255	0.152	0.407
change	0.144	0.039	0.183
% of total increase	78.85	21.15	100.00

(c) Large firms			
	between firm	within firm	total variance
1985	0.104	0.156	0.260
2018	0.307	0.170	0.477
change	0.203	0.014	0.217
% of total increase	93.52	6.48	100.00

Small firm: 10-49 employees; medium-sized firm: 50-249 employees; large firm: over 250 employees.

Table 2.15: Between vs within sector variance decomposition (Italy, weekly wages)

(a) Change over time			
	between sector	within sector	total variance
1985	0.061	0.180	0.240
2018	0.152	0.295	0.447
change	0.092	0.115	0.207
% of total variance increase	44.23	55.77	100.00

(b) Shares			
	between sector share	within sector share	total
1985	25.326	74.674	100.00
2018	34.071	65.929	100.00

Table 2.16: Controlling for sector of the firm: between vs within firm variance decomposition (Italy, weekly wages)

(a) Change over time			
	between firm	within firm	total variance
1985	0.057	0.123	0.180
2018	0.138	0.156	0.295
change	0.082	0.033	0.115
% of total increase	71.02	28.98	100.00

(b) Shares			
	between firm share	within firm share	total
1985	31.50	68.50	100.00
2018	46.96	53.04	100.00

Table 2.17: Sector and firm: full variance decomposition (Italy, weekly wages)

(a) Change over time				
	between sector	between firms within sector	within firm	total variance
1985	0.061		0.123	0.240
2018	0.152		0.156	0.447
change	0.092		0.033	0.207
% of total increase	44.23		16.16	100.00

(b) Shares				
	between sector share	between firms within sector share	within firm share	total
1985	25.33		51.15	100.00
2018	34.07		34.97	100.00

Table 2.18: Controlling for sector of the worker: between vs within firm variance decomposition (Italy, weekly wages)

(a) Change over time			
	between firm	within firm	total variance
1985	0.056	0.123	0.180
2018	0.137	0.157	0.295
change	0.081	0.034	0.115
% of total increase	70.29	29.71	100.00

(b) Shares			
	between firm share	within firm share	total
1985	31.43	68.57	100.00
2018	46.61	53.39	100.00

Table 2.19: Sector of the worker and firm: full variance decomposition (Italy, weekly wages)

(a) Change over time				
	between sector	between firms within sector	within firm	total variance
1985	0.061	0.056	0.123	0.240
2018	0.153	0.137	0.157	0.447
change	0.092	0.081	0.034	0.207
% of total increase	44.40	39.09	16.52	100.00

(b) Shares				
	between sector share	between firms within sector share	within firm share	total
1985	25.33	23.47	51.20	100.00
2018	34.15	30.69	35.16	100.00

Table 2.20: Song et al. (2019): Between vs within firm variance decomposition (USA, annual earnings)

(a) Change over time			
	between firm	within firm	total variance
1981	0.222	0.430	0.652
2013	0.357	0.489	0.846
change	0.135	0.059	0.194
% of total increase	69.59	30.41	100.00

(b) Shares			
	between firm share	within firm share	total
1981	34.05	65.95	100.00
2013	42.20	57.80	100.00

Figures in this table are derived from Table 2 in Song et al. (2019).

Table 2.21: Song et al. (2019): Between vs within sector variance decomposition (USA, annual earnings)

(a) Change over time			
	between sector	within sector	total variance
1981	0.135	0.517	0.652
2013	0.141	0.705	0.846
change	0.006	0.188	0.194
% of total variance increase	3.09	96.91	100.00

(b) Shares			
	between sector share	within sector share	total
1981	20.706	79.294	100.00
2013	16.667	83.333	100.00

Figures in this table are derived from Table 2 in Song et al. (2019).

Table 2.22: Song et al. (2019): Controlling for sector of the firm: between vs within firm variance decomposition (USA, annual earnings)

(a) Change over time			
	between firm	within firm	total variance
1981	0.088	0.429	0.517
2013	0.216	0.489	0.705
change	0.128	0.060	0.188
% of total increase	68.09	31.91	100.00

(b) Shares			
	between firm share	within firm share	total
1981	17.02	82.98	100.00
2013	30.64	69.36	100.00

Figures in this table are derived from Table 2 in Song et al. (2019).

Table 2.23: Song et al. (2019): Sector and firm, full variance decomposition (USA, annual earnings)

(a) Change over time					
	between sector	between firms within sector	within firm	total variance	
1981	0.135	0.088	0.429	0.652	
2013	0.141	0.216	0.489	0.846	
change	0.006	0.128	0.060	0.194	
% of total increase	3.09	65.98	30.93	100.00	

(b) Shares					
	between sector share	between firms within sector share	within firm share	total	
1981	20.71	13.50	65.80	100.00	
2013	16.67	25.53	57.80	100.00	

Figures in this table are derived from Table 2 in Song et al. (2019).

Table 2.24: Between vs within collective agreement variance decomposition (Italy, annual earnings)

(a) Change over time			
	between col. agreement	within col. agreement	total variance
1985	0.103	0.382	0.486
2018	0.204	0.519	0.723
change	0.101	0.136	0.237
% of total increase	42.64	57.36	100.00

(b) Shares			
	between col. agreement share	within col. agreement share	total
1985	21.24	78.76	100.00
2018	28.27	71.73	100.00

Table 2.25: Collective agreement and firm: full variance decomposition (Italy, annual earnings)

(a) Change over time				
	between col. agreement	between firms within col. agreement	within firm	total variance
1985	0.103	0.131	0.252	0.486
2018	0.204	0.173	0.345	0.723
change	0.101	0.042	0.094	0.237
% of total increase	42.64	17.90	39.45	100.00

(b) Shares				
	between col. agreement share	between firms within col. agreement share	within firm share	total
1985	21.24	26.92	51.84	100.00
2018	28.27	23.96	47.77	100.00

Table 2.26: Between vs within collective agreement variance decomposition (Italy, weekly wages)

(a) Change over time			
	between col. agreement	within col. agreement	total variance
1985	0.066	0.174	0.240
2018	0.128	0.319	0.447
change	0.062	0.145	0.207
% of total increase	29.75	70.25	100.00

(b) Shares			
	between col. agreement share	within col. agreement share	total
1985	27.61	72.39	100.00
2018	28.60	71.40	100.00

Table 2.27: Collective agreement and firm: full variance decomposition (Italy, weekly wages)

(a) Change over time				
	between col. agreement	between firms within col. agreement	within firm	total variance
1985	0.066	0.064	0.110	0.240
2018	0.128	0.174	0.146	0.447
change	0.062	0.110	0.035	0.207
% of total increase	29.74	53.15	17.11	100.00

(b) Shares				
	between col. agreement share	between firms within col. agreement share	within firm share	total
1985	27.61	26.55	45.84	100.00
2018	28.60	38.85	32.55	100.00

Figures

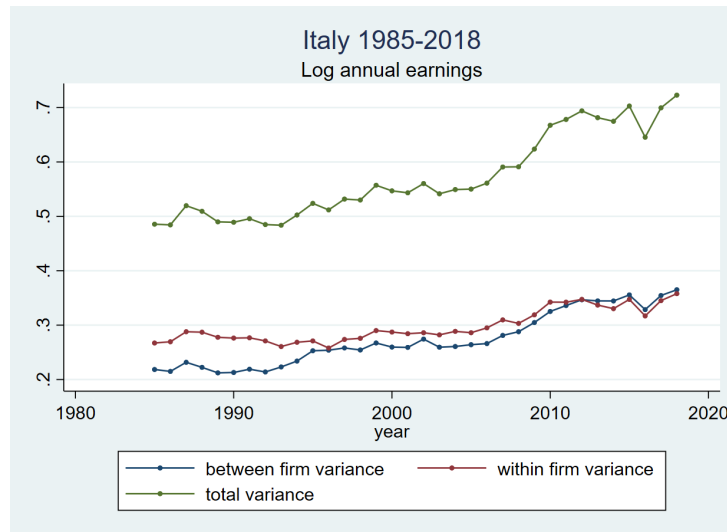
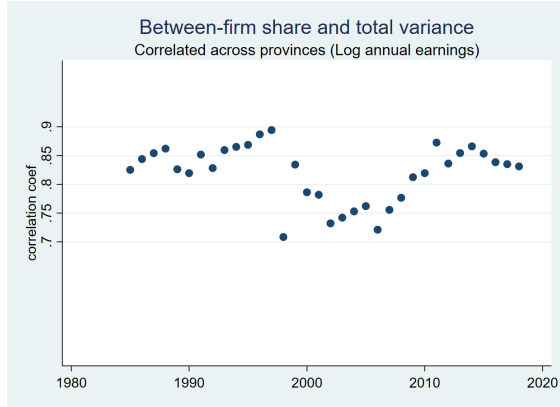


Figure 2.1: Between vs within firm variance in Italy 1985-2018 (annual earnings).

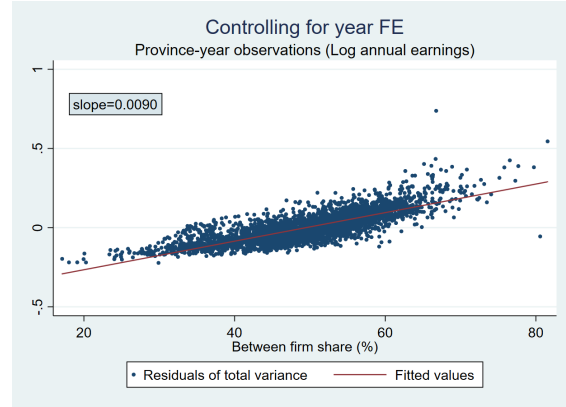


Figure 2.2: Different firm sizes: between vs within firm variance in Italy 1985-2018 (annual earnings).

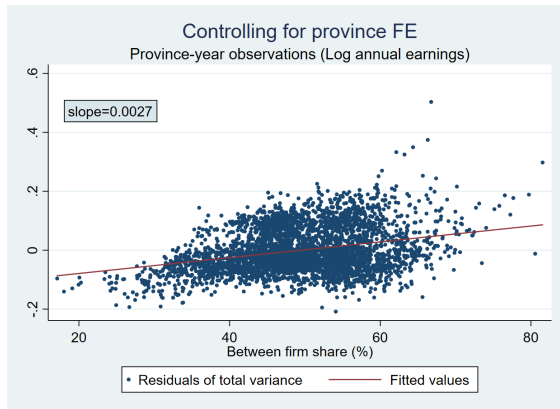
Small firm: 10-49 employees; medium-sized firm: 50-249; large firm: over 250 employees.



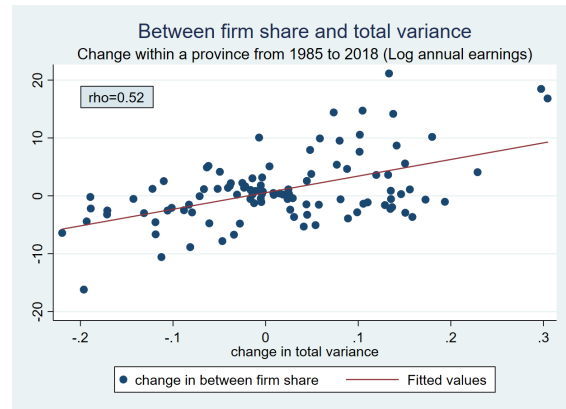
(a) The correlation coefficient of the between firm share and the total variance across provinces plotted over time.



(b) Total variance of log annual earnings for each province-year pair regressed on year fixed effects. The resulting residuals regressed on between-firm variance share.



(c) Total variance of log annual earnings for each province-year pair regressed on province fixed effects. The resulting residuals regressed on between-firm variance share.



(d) Change in the between-firm share and in the total variance between 1985 and 2018 plotted for each province.

Figure 2.3: Between-firm variance share and the total variance across Italian provinces and time(annual earnings).

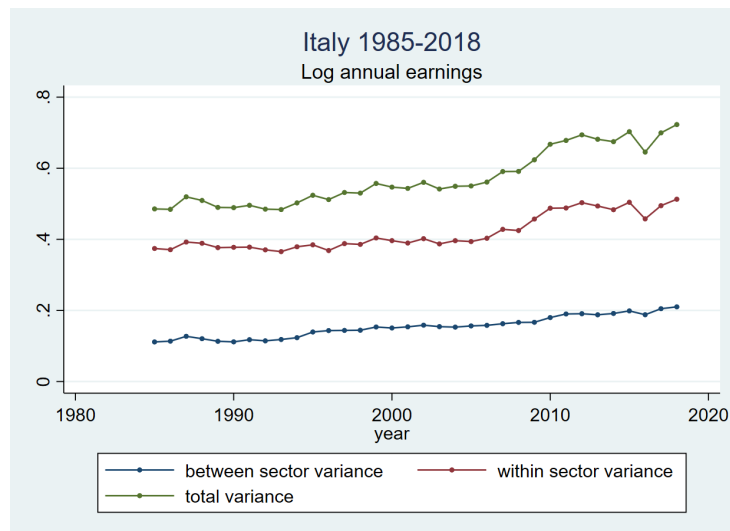
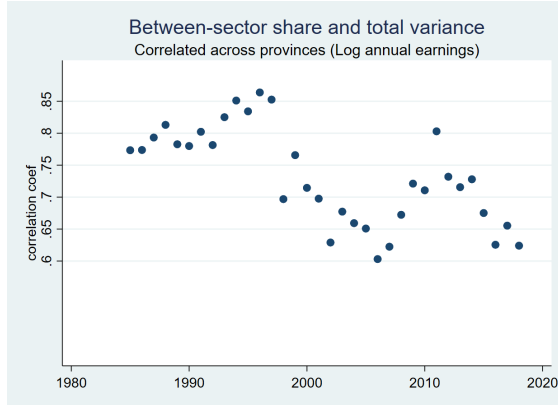
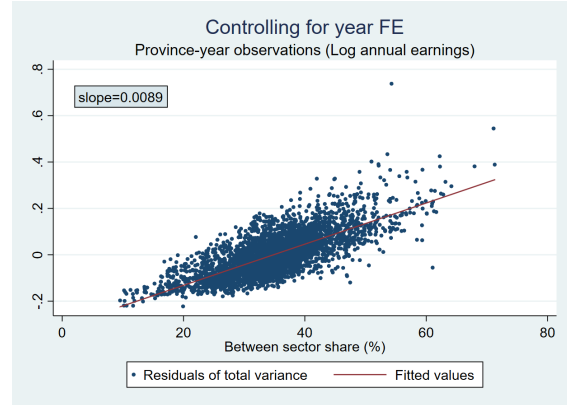


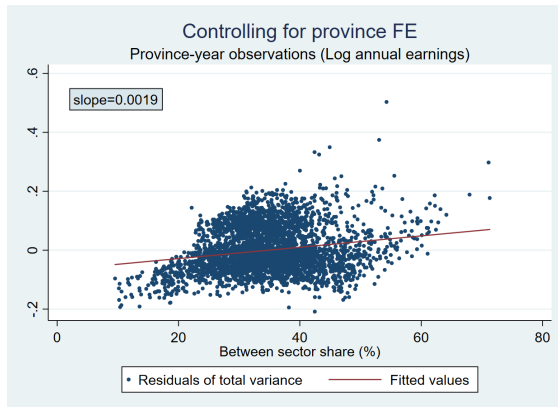
Figure 2.4: Between vs within sector variance in Italy 1985-2018 (annual earnings).



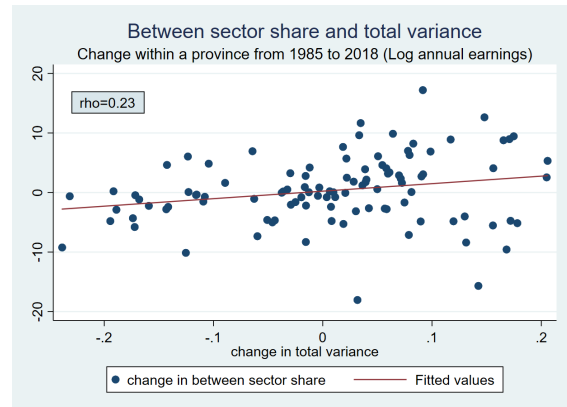
(a) The correlation coefficient of the between sector share and the total variance across provinces plotted over time.



(b) Total variance of log annual earnings for each province-year pair regressed on year fixed effects. The resulting residuals regressed on between-sector variance share.

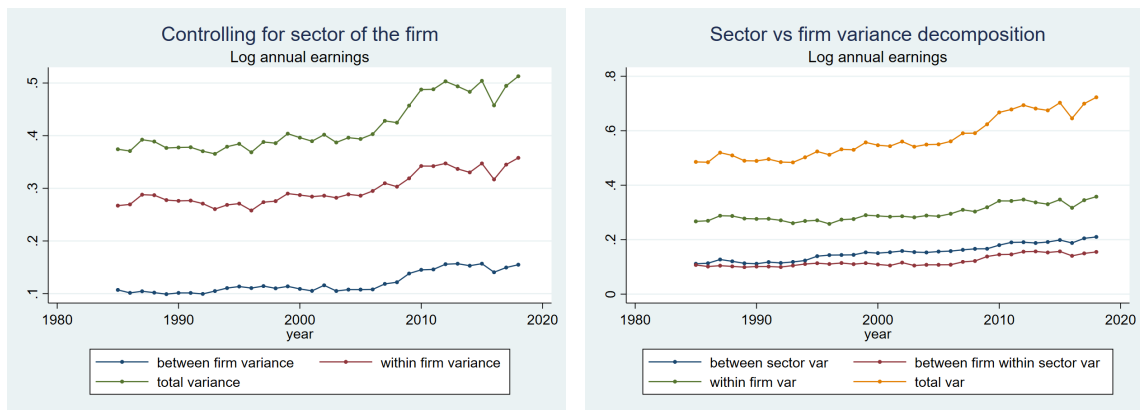


(c) Total variance of log annual earnings for each province-year pair regressed on province fixed effects. The resulting residuals regressed on between-sector variance share.



(d) Change in the between-sector share and in the total variance between 1985 and 2018 plotted for each province.

Figure 2.5: Between-sector variance share and the total variance across Italian provinces and time (annual earnings).



(a) Controlling for sector of the firm: between vs within firm variance decomposition. (b) Sector and firm: full variance decomposition.

Figure 2.6: Sector and firm variance decomposition for the whole of Italy (annual earnings).

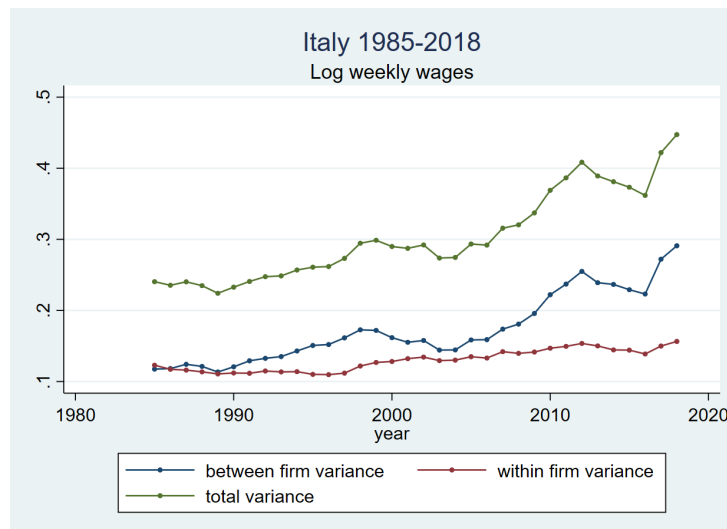


Figure 2.7: Between vs within firm variance in Italy 1985-2018 (weekly wages).

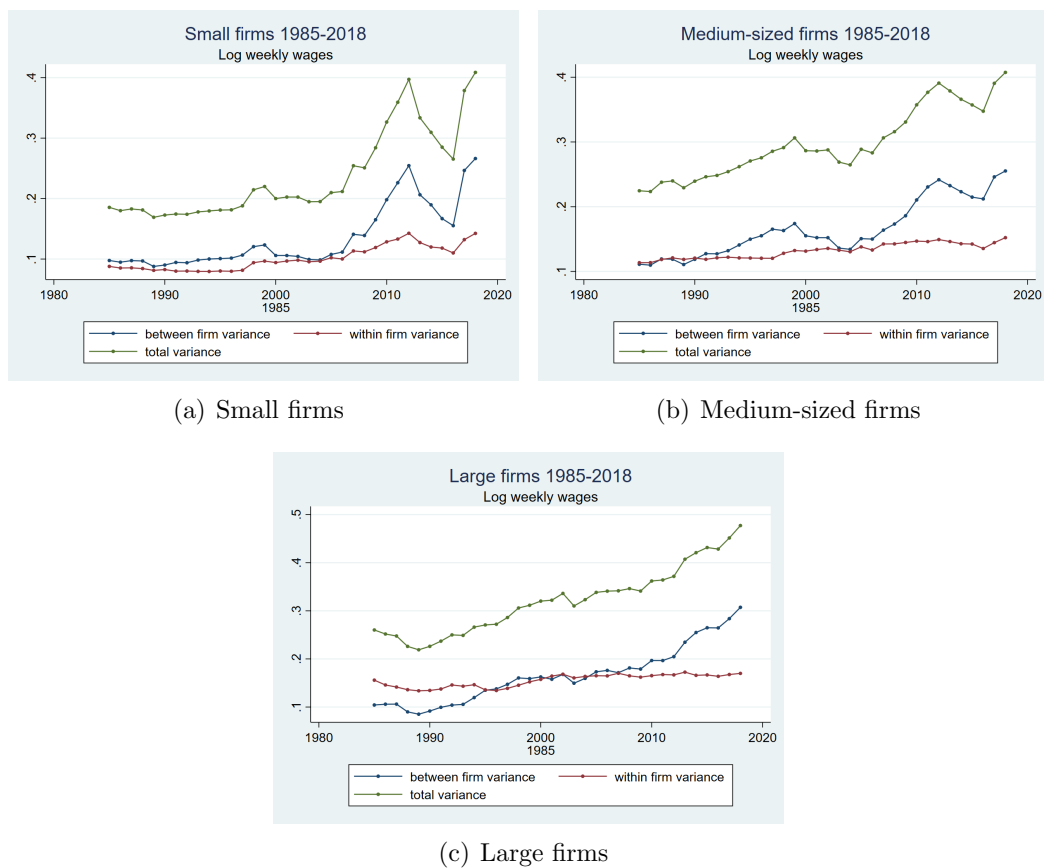
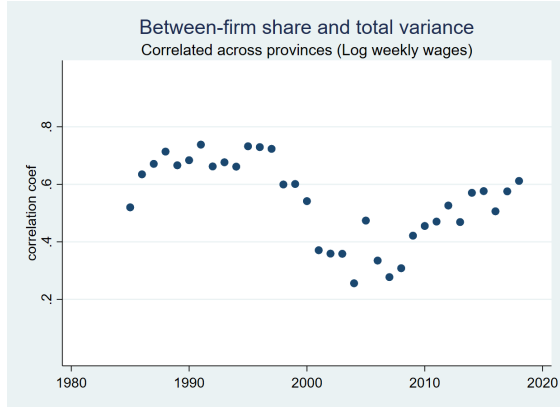
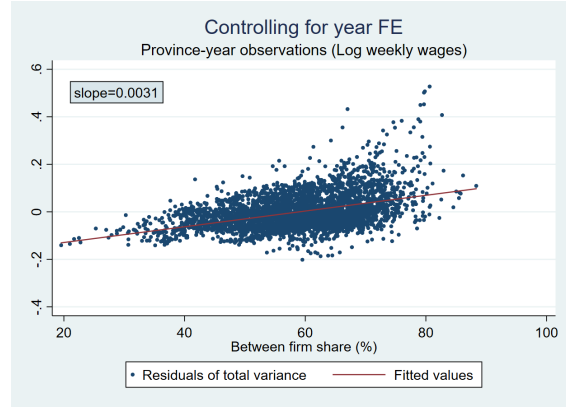


Figure 2.8: Different firm sizes: between vs within firm variance in Italy 1985-2018 (weekly wages).

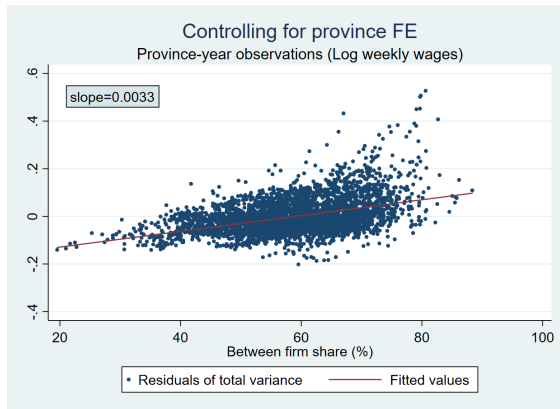
Small firm: 10-49 employees; medium-sized firm: 50-249 employees; large firm: over 250 employees.



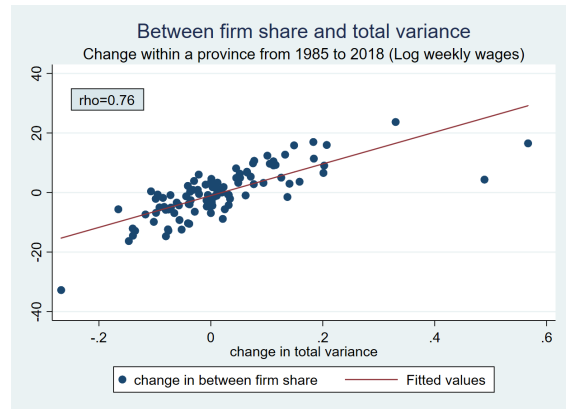
(a) The correlation coefficient of the between firm share and the total variance across provinces plotted over time.



(b) Total variance of log weekly wages for each province-year pair regressed on year fixed effects. The resulting residuals regressed on between-firm variance share.



(c) Total variance of log weekly wages for each province-year pair regressed on province fixed effects. The resulting residuals regressed on between-firm variance share.



(d) Change in the between-firm share and in the total variance between 1985 and 2018 plotted for each province.

Figure 2.9: Between-firm variance share and the total variance across Italian provinces and time(weekly wages).

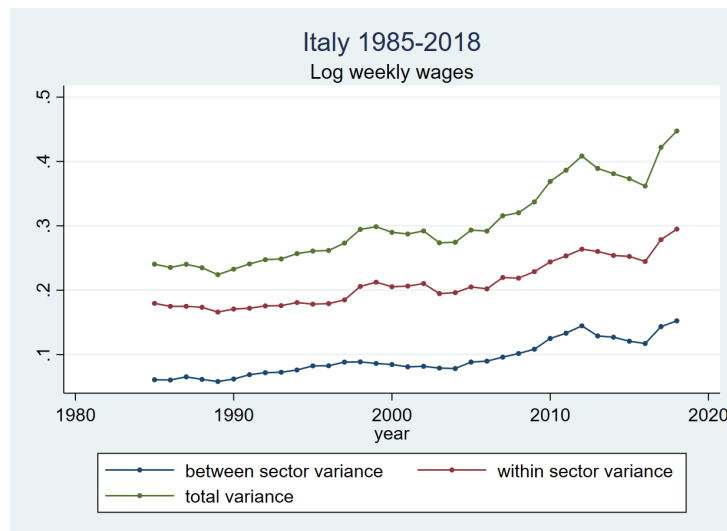
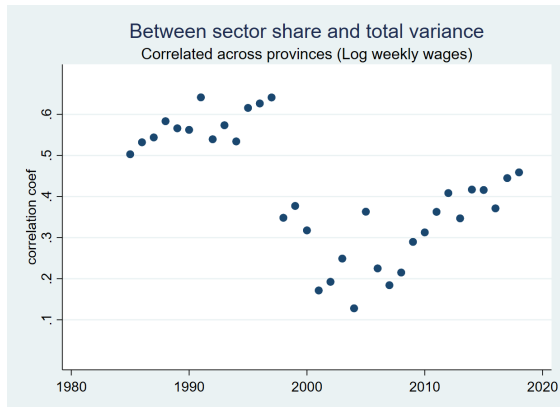
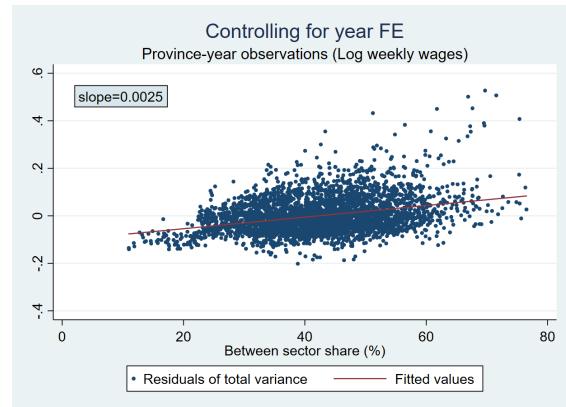


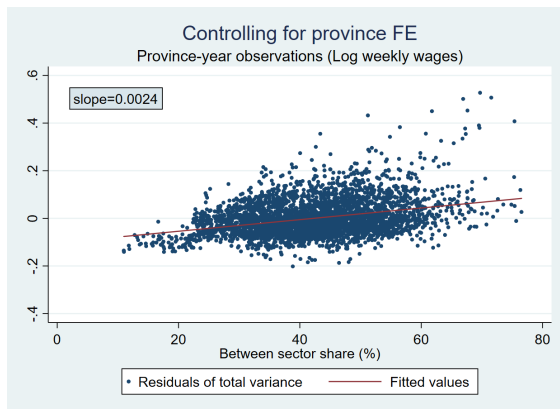
Figure 2.10: Between vs within sector variance in Italy 1985-2018 (weekly wages).



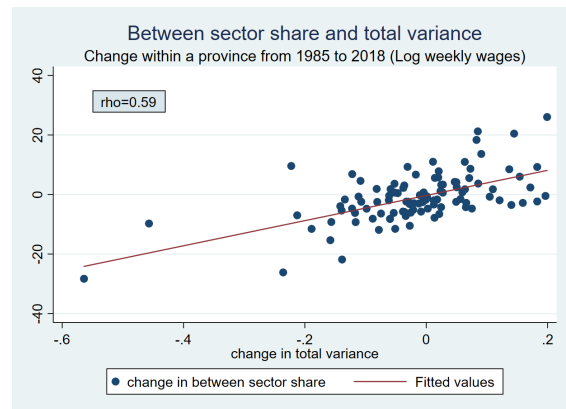
(a) The correlation coefficient of the between sector share and the total variance across provinces plotted over time.



(b) Total variance of log weekly wages for each province-year pair regressed on year fixed effects. The resulting residuals regressed on between-sector variance share.

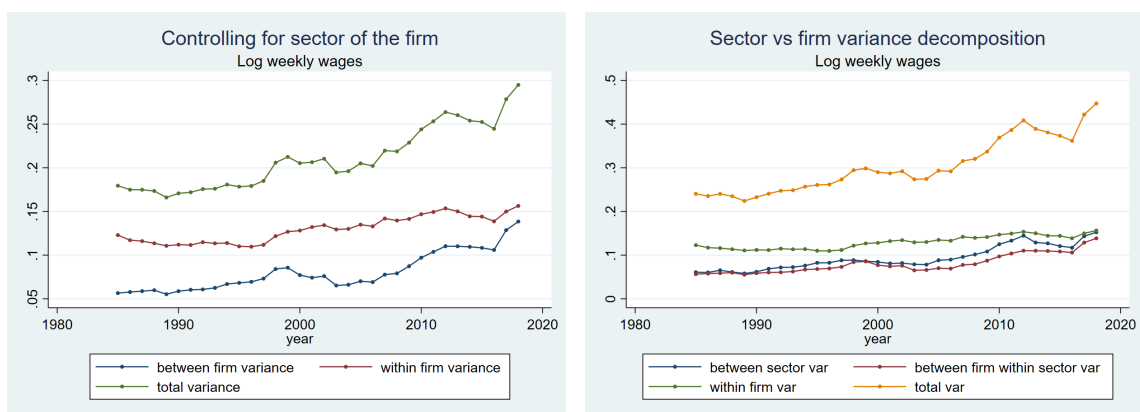


(c) Total variance of log weekly wages for each province-year pair regressed on province fixed effects. The resulting residuals regressed on between-sector variance share.



(d) Change in the between-sector share and in the total variance between 1985 and 2018 plotted for each province.

Figure 2.11: Between-sector variance share and the total variance across Italian provinces and time (weekly wages).



(a) Controlling for sector of the firm: between vs within firm variance decomposition. (b) Sector and firm: full variance decomposition.

Figure 2.12: Sector and firm variance decomposition for the whole of Italy (weekly wages).

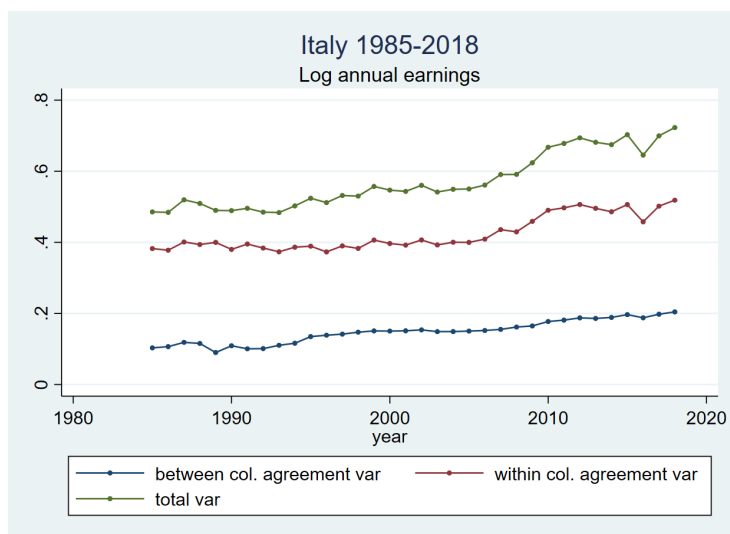


Figure 2.13: Between vs within collective agreement variance in Italy 1985-2018 (annual earnings).

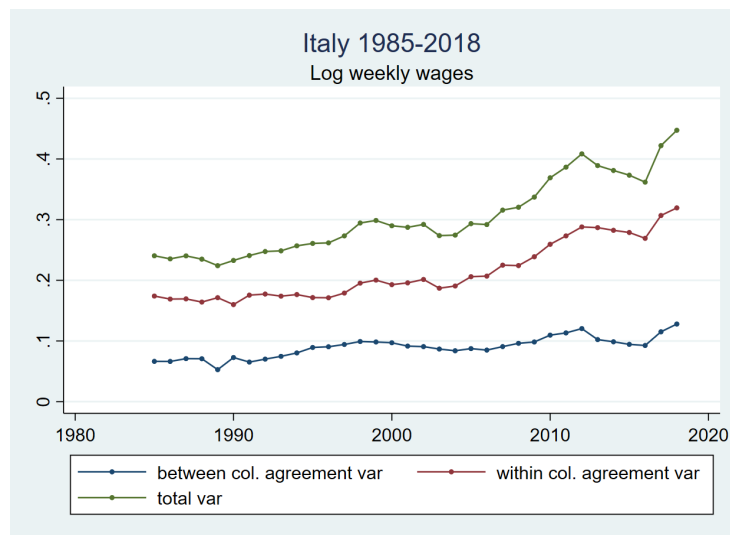


Figure 2.14: Between vs within collective agreement variance in Italy 1985-2018 (weekly wages).

Chapter 3

The Aggregate Implications of Sector-Level vs Firm-Level Wage Setting in a Frictional Labour Market

3.1 Introduction and Related Literature

In this chapter I examine the degree to which wage dispersion among homogeneous workers that is driven by firm characteristics varies with different wage setting institutions and the effects of this type of wage dispersion for firm dynamics and for aggregate outcomes. There are very large and persistent productivity differences among firms in very narrowly defined industries (Syverson (2011)) and these productivity differences seem to spill over into wages. Many studies show that more productive and larger employers systematically pay substantially higher wages than others to workers with similar observable skills performing the same occupations (Dickens (1987), Krueger and Summers (1988), Lamadon, Mogstad, and Setzler (2019)). Studies that use longitudinal data on workers switching between firms typically find that about 5% to 20% of total wage dispersion can be explained by firms' pay policies after controlling for quality of their labour force (Abowd, Kramarz, and Margolis (1999), Card, Heining, and Kline (2013), Song et al. (2019)). Furthermore, studies on rent sharing find elasticities of wages with respect to value added per worker in the range of 0.05–0.15

(Card, Cardoso, et al. (2018)). In Western European countries typically over 80% of workers are covered by some form of collective wage bargaining (Visser (2016)). In majority of these countries the main level at which wage bargaining takes place is the sector. However, there has been a shift towards decentralisation since late 1980s and firm-level bargaining has gained importance (Ortigueira (2013)). The optimal level at which wages should be negotiated is a contested issue that is very important for current policy debates.

I build a search model where firms have multiple workers and are heterogeneous in productivity whereas workers are homogeneous. There is an endogenous firm entry in the spirit of Hopenhayn (1992) and Melitz (2003). Firms pay a fixed cost of entry and then learn their time-invariant productivity. They only stay and start producing if the value of the firm, the discounted sum of future expected profits and losses, is positive. There is a threshold productivity level which is defined as the level of productivity where a newly created firm is indifferent between staying or exiting. There are decreasing returns to scale in production. The costs of recruitment are assumed to be convex. This is supported by empirical studies that use direct data on recruitment costs (Manning (2006), Blatter, Muehlemann, and Schenker (2012)). Because the marginal recruitment cost is increasing in the number of hires in a given time period firms only gradually grow towards their target size. More productive firms have a larger target size. Thus the model produces dispersion in firm size for two reasons, time-consuming hiring and differences in permanent firm productivity. The model is most similar to Acemoglu and Hawkins (2014), but it is in discrete time and contains fixed costs of production which give rise to the threshold level of firm productivity and a firm selection mechanism.

Individual wage bargaining in the model follows Stole and Zwiebel (1996). Each worker is treated as marginal, because the outside option of the worker is unemployment and the outside option of the firm is to continue producing with the remaining workers. The individually-bargained wage is an increasing function of the firm's marginal product of labour. Individual wage setting is contrasted with two-tier collective wage bargaining where first a tariff wage

is set at the sector level and then additional wage premiums are bargained collectively at the firm level. This section of the model follows closely the framework of collective wage bargaining in the Scandinavian countries (Barth, Moene, and Willumsen (2014)). Wage is equal to the tariff wage plus a wage premium. Sector-wide union and employer organisation negotiate over the tariff wage. The threat point is the possibility of a strike where for one period firms cannot produce, but they also do not pay wages. Strike is only temporary, both parties return to the negotiating table in the next period. The tariff wage is an increasing function of the industry's average output per worker. Provided that sector-level negotiators reached an agreement and industry-wide strike had been avoided, firm-level worker representatives bargain with owners of the firms over the wage premiums. At the firm-level workers cannot go on a strike, but they can engage in work-to-rule actions where they follow work instructions in a pedantic manner¹. Thus they reduce their effort by a small amount and use this as a threat to extract wage premiums from the firm. The wage premium is an increasing function of the firm's output per worker. The model can capture different degrees of centralisation of collective wage bargaining by varying the extent to which workers can reduce their effort during a pay dispute with their firm and thus adjusting the effective worker bargaining power at firm-level. The greater is the bargaining power of workers at firm-level, the larger is the dispersion of wages across firms under collective bargaining.

Under both individual bargaining and collective bargaining where workers have some firm-level bargaining power and thus wage premiums are paid the wage is increasing in the firm's permanent productivity and it is decreasing in the firm's employment level. Because of decreasing returns to scale, gradual growth in employment and the fact that the firm's productivity is time-invariant, in both cases the wage that the firm pays is declining in the firm's age and thus younger firms pay a wage premium. This is in line with the empirical results of Schmieder (2013) and Babina et al. (2019). Once at the target size, more productive firms are not only larger, but also pay higher wages, as they face a higher cost of replacing

¹Thus workers do tasks and duties that are specifically outlined in their contracts, but they do not do anything extra and they show no initiative.

a worker due to convexity of the recruitment cost. In both settings a firm with a higher permanent productivity will face a higher wage rate along its entire growth path.

I explore the aggregate outcomes of reducing the wage dispersion across firms. I am particularly interested in changes in total value added which is equal to total production of the final good minus the three types of costs that are a deadweight loss in the model (firm entry, fixed and recruitment costs). First, there is a *Firm Entry Effect*. Under firm-level wage bargaining (either individual or collective) firms face high wage costs when they are far from their target size and this reduces their profitability in the first periods of their life. Reducing this young firm wage premium increases firm profitability in the early periods which due to discounting has a large positive effect on the value of firms. The larger is the discounting of future profits, the stronger is this effect. More entry raises the stock of firms as well as total employment and production. This increases total value added. On the other hand, greater entry and fixed costs lower total value added. Thus the overall effect on total value added is ambiguous.

Second, there is a *Firm selection effect*. On one hand, a compression of wage dispersion across firms reduces the young firm wage premium. This means that firms save on wage costs in the early periods of their life and that they can afford to grow more slowly, saving on convex recruitment costs. This boost in profitability of firms of all productivity levels enables even less productive firms to survive in the sector. On the other hand, under firm-level wage bargaining, a firm with higher permanent productivity faces a higher wage than a firm with lower permanent productivity along its entire growth path. Wage compression means that high and low productivity firms face the same wage rates. This enforces stricter selection of firms with a higher threshold productivity. Ex ante it is unclear which of the two opposing effects will dominate.

Third, under firm-level bargaining wage is an increasing function of either marginal product of labour (individual bargaining) or average product of labour (collective bargaining). Due to decreasing returns to scale wages are decreasing in firm size and hence firms can

lower the wage that they face by hiring more workers. As E. Smith (1999) and Cahuc and Wasmer (2001) have found for the case of individual wage bargaining and Bauer and Linsgens (2013) for the case of firm-level unions, this leads to an over-employment effect. Firms grow to a larger size than they would if there was perfectly competitive labour market and wage was independent of firm size. In my model when wage dispersion across firms is reduced (via greater centralisation of wage bargaining) the relationship between firm size and wage is weakened and thus firms have smaller incentives to over-hire. This lowers the average size of firms (*Firm size effect*). Due to decreasing returns to scale a lower average firm size raises the average output per worker in the economy. The total value added rises for two reasons: because firms are smaller they save resources on recruitment costs and the average output per worker is higher. Therefore we can see that while the decision about when to stop growing under firm-level wage bargaining is privately efficient for the firm (the firm is maximising its value) it may be very inefficient from the point of view of a social planner that is maximising the total value added in the economy.

I solve the model numerically and calibrate it using the method of simulated moments, thus matching model-generated moments with selected data moments. I present a model with individual wage bargaining that is calibrated to match US data moments, as well as a model with two-tier collective wage bargaining calibrated to match Swedish data moments. I compare the two cases and also run three counterfactual experiments. First, I apply completely centralised sector-level wage bargaining to the USA. I compare aggregate outcomes under individually-bargained wages with sector level bargaining for different levels of bargaining power of the sector-level union. I am particularly interested in the model economy with sector bargaining where the average wage is the same as in the individual wage bargaining case. Second, I take the model economy with individual wage bargaining that is calibrated to the USA and simultaneously reduce bargaining power of workers in individual negotiations and increase the worker outside option. I focus on such combinations of the two parameters where the mean wage remains the same. In this way I am reducing wage disper-

sion among homogeneous workers while keeping the average wage level the same. Third, I take the model economy with two-tier collective bargaining that is calibrated to Sweden and I investigate the effects of changes in the firm-level worker bargaining power.

The main finding from all the counterfactual experiments is that wage compression where the average wage remains the same tends to have positive effects on total value added as total production rises by more than the three types of deadweight loss in the model: firm entry, fixed and recruitment costs. There are two main factors that contribute to this. The first one is the *Firm entry effect*. Reducing the young firm wage premium is similar to lowering the cost of creating firms. Thus there is more firm entry and a larger stock of firms. The second one is the *Firm size effect*. Weakening the link between wages and the firm's marginal (average) product of labour reduces the incentive for firms to over-hire and thus results in lower average firm size. Both effects contribute towards a larger total production of the final good. Lower average firm size leads to lower total recruitment costs while more entry leads to larger total entry and fixed costs. However, in all of my simulations the net effect is that total production rises by more than the three types of costs and thus total value added rises. Finally, this kind of mean-preserving wage compression seems to reduce the firm productivity threshold.

To sum up, this chapter argues that the wage dispersion driven by firm characteristics via rent sharing has negative efficiency implications as it discourages firm entry and encourages over-employment by firms. Furthermore, I show that centralisation of wage bargaining can reduce wage dispersion across firms and thus result in better aggregate outcomes.

This chapter contributes to four strands of literature. First, there is a new, emerging literature that identifies young firm wage premium. Babina et al. (2019) use US data and find that while young firms on average pay lower wages, after controlling for firm and worker time-invariant heterogeneity using fixed effects there is a statistically significant young-firm pay premium that is monotonically decreasing with firm age. They find that firms aged one year or less pay 6.4 log point wage premium compared to firms older than 20 years.

Schmieder (2013) uses German data and finds that after controlling for establishment and worker fixed effects, establishments aged one year or less pay on average a wage premium of 10% compared to establishments over 20 years old. I provide a novel theoretical explanation for these empirical results. When firms are young they have few workers relative to their target size and thus their marginal product of labour is relatively high. In individual negotiations a worker can threaten to leave and it takes time and resources to replace him. When a firm is young each worker is more valuable to the company than when the firm is older and it had time to grow to its target size.

Second, I contribute to the literature that builds search models with multi-worker firms that are heterogeneous in productivity. In the seminal paper of Elsby and Michaels (2013) hiring costs are linear, but there is wage dispersion because of idiosyncratic shocks to firm productivity. In Acemoglu and Hawkins (2014) wages vary across heterogeneous firms because of convexity of recruitment cost. Both papers assume decreasing returns to scale in production. There are a number of papers that apply the large-firm search model to the analysis of international trade or product market deregulation (Felbermayr, Prat, and Schmerer (2011), Felbermayr and Prat (2011)). These models assume constant returns to scale in production and generate decreasing marginal revenue product of labour as a result of monopolistic competition in the product market. Furthermore, they include firm selection mechanism as a result of the presence of fixed costs of production. However, they assume linear recruitment cost and there are no firm-level shocks and hence firms of all productivity levels pay the same wage. Bauer and Lingens (2013) is the only paper that includes firm-level collective bargaining in a large-firm search model setting. However, firms are assumed to be homogeneous in productivity and thus there is a single wage rate in the economy and no firm selection. My paper is the first that includes both variation in wages across firms and firm selection mechanism.

Third, there are studies that compare the effects of sector-level unions with firm-level unions and find that equalisation of wages across firms that are heterogeneous in produc-

tivity leads to a higher threshold level of firm productivity and to a higher average labour productivity². The main way in which these papers differ from one another is in the assumptions that they make in order to generate wages that are increasing in firm productivity. Moene and Wallerstein (1997) use vintage capital model where productivity of a plant is simply a function of its age and workers use the threat of a strike to extract higher wages. The main limitation is that the employment level of plants is assumed to be fixed. The model in Braun (2011) uses variable demand elasticity, but lacks general equilibrium effects. Pinto (2017) presents a model with monopolistic competition, CES demand and "rent-sharing motives". Pinto (2017) assumes that workers have relative preferences where they compare their wage payments with the profit of the firm at which they are employed. If the firm's profits go up and the wages remain unchanged then workers lose utility. Unlike the studies above, my model includes two-tier wage bargaining which is both a better description of how collective bargaining works in real life and offers the ability to adjust the degree of centralisation of collective bargaining in the model.

Fourth, there are models where rent sharing is generated as a result of search frictions and sector-level wage-setting is compared with individually bargained wages (Boeri and Burda (2009), Jimeno and Thomas (2013), Vona and Zamparelli (2014)). However, these models only feature single-worker firms and constant returns to scale. Therefore they are unable to shed light on how the wage bargaining between a worker and a firm is influenced by how many other workers the firm has. Furthermore, these models say nothing about firm dynamics under different wage-setting regimes given that the unit of analysis is a match, not a firm.

Finally, this paper is the first to introduce collective wage bargaining at different levels of centralisation into a large firm search model and to compare its aggregate implications to individual wage bargaining. I provide two novel arguments in favour of sector-level bar-

²This channel has first been proposed by the architects of the "Scandinavian model" Gösta Rehn and Rudolf Meidner in the 1950s and it has been influential in debates about the merits of centralised wage bargaining in the Scandinavian countries (Rehn (1952)).

gaining. Firstly, centralised wage setting can reduce the young firm wage premium and thus encourage more firm entry. Secondly, it can weaken the link between firm size and wages and thus reduce the inefficiencies associated with the over-employment effect which has been identified by the existing literature.

3.2 Model

3.2.1 Model Setting

The model is in discrete time. There is a mass of homogeneous workers equal to N who each supply one unit of labour inelastically. Both firms and workers are risk-neutral and discount future at the rate r . Firms produce a homogeneous good with price normalised to 1. All costs in the model are measured in units of this single good. All firms face the same fixed cost of operating $F^p > 0^3$, but they have different productivity levels z . Firm entry is in the spirit of Hopenhayn (1992) and Melitz (2003). Every period a firm can be created and enter the market by paying an entry cost F^e . When a firm enters, it draws the level of its idiosyncratic productivity $z > 0$ from a distribution that has probability density function $f(z)$ and cumulative density function $F(z)$. z is then constant over the life of the firm⁴. In the first period after entry a firm has no workers.

Because of the fixed costs of production not all firms that enter the industry will actually produce. After the new firm learns its productivity, it will decide to exit if the value of the firm (the sum of discounted future profits and losses) is negative. This happens if the productivity draw is too low. Hence there will be a minimum level of productivity z^* that a

³I think of F^p as the costs that a firm has to pay in order to simply continue existing such as the costs of red tape. When calibrating the model I use an estimate of administrative costs of government regulation as a target for $F^p > 0$.

⁴There are very large productivity differences among firms in very narrowly defined industries and these differences are very persistent across time. For example within 4-digit industries in the US manufacturing sector the plant at the 90th percentile of the productivity distribution makes almost twice as much output with the same measured inputs as the 10th percentile plant. Secondly, regressing a producer's current TFP on its one-year lagged TFP yields autoregressive coefficients on the order of 0.6 to 0.8 (Syverson (2011)). For this reason the model focuses on time-invariant productivity differences between firms.

firm needs to have in order to operate in the market.

Labour is the only input in production. Production function $y(n, z)$ exhibits decreasing returns to scale. I assume the standard Cobb-Douglas form.

$$y(n, z) = zn^\alpha \quad (3.1)$$

where $\alpha \in (0, 1)$. At every point in time, firm's employment level n is predetermined and cannot be increased instantaneously due to the search friction.

The cost of posting vacancies $c(v)$ is assumed to be convex and thus marginal cost of vacancy posting $c'(v)$ is increasing in the number of vacancies posted in the same time period:

$$\begin{aligned} c(v) &= \lambda v + \frac{1}{2}\gamma v^2 \\ c'(v) &= \lambda + \gamma v \end{aligned} \quad (3.2)$$

where λ captures the linear component of hiring cost and γ captures the convex part.

I assume that the recruitment cost is convex and not linear for the following three reasons. First, empirical studies that use direct information on firm recruitment costs (includes the cost of posting vacancies, advertising and screening) show that recruitment costs are convex in the number of hires for a given time period (Manning (2006), Blatter, Muehlemann, and Schenker (2012)). They also find that larger firms face higher average hiring costs. Additionally, Blatter, Muehlemann, and Schenker (2012) find that while the degree of convexity is smaller in the large firms (over 100 employees), because they hire so many workers they still pay approx. 4 times more per worker hired than the smallest firms. Second, with linear vacancy cost firms post very large number of vacancies in very short time and they jump straight to their target size $n^*(z)$. With convex recruitment cost firms only gradually grow towards their target size. Third, due to convexity of recruitment cost, larger firms face higher cost of replacing a worker. Because of this even when firms had time to adjust their employment to the desired level (every firm is at its target size $n^*(z)$) marginal products

of labour are not equalized across firms and thus more productive firms are paying higher wages than less productive firms in equilibrium with individual wage bargaining.

Matching is random. The number of matches between workers and firms per unit time is given by the aggregate matching function $M(u, v_{tot})$. M is an increasing, concave function of the measure of total vacancies v_{tot} and the measure of total unemployed workers u and it has constant returns to scale. Each firm meets a worker at a Poisson rate $q(\theta) = v \frac{M(u, v_{tot})}{v_{tot}}$ that is proportional to v , the number of vacancies that it posts. In other words the time it takes to hire one worker is lower the more vacancies you post. An unemployed worker meets some firm at a Poisson rate $\theta q(\theta) = \frac{M(u, v_{tot})}{u}$ that is identical across workers. The market tightness is given by $\theta = \frac{v_{tot}}{u}$.

Individual matches between firms and workers are destroyed at an exogenous Poisson rate $s \in (0, 1)$. This ensures that firms have to post vacancies even if they only want to stay at their current size, because they have to replace the workers that they are losing due to exogenous separation. Firms themselves are destroyed at an exogenous Poisson rate $\delta \in (0, 1)$. This ensures that in equilibrium there is continuous firm entry and exit. Every period some firms are entering and some firms are exiting the industry. In the steady-state the inflows and outflows of firms are equal to each other such that the stock of firms is constant. When a firm is destroyed all of its workers become unemployed. These two shocks are independent across firms and across employed workers.

Let us consider firm dynamics in the model. A new firm has very few employees and thus it has a high marginal product of labor. Therefore the firm chooses to post many vacancies and to grow quickly. However, because of the convex hiring cost, its speed of growth is finite. As the firm grows, its marginal product of labour falls and it reduces the intensity of hiring. The firm is growing towards its target size n^* which is defined as the level of employment where the new hires are only large enough to offset the departing workers that the firm is losing because of exogenous separations. I show in later section that under both individual and collective wage bargaining firms with larger time-invariant productivity z have a larger

target size $n^*(z)$. In equilibrium there is firm size dispersion for two reasons: 1.) differences in firm productivity implying different target sizes and 2.) time-consuming hiring that leads to firms of different age being at different distance from their respective target sizes.

3.2.2 Firm and Worker Value Functions

Each firm chooses a path for vacancies to maximize the sum of discounted future expected profits while taking the macroeconomic variables (e.g. the labor market tightness), and the law of motion of its workforce as given. Firms open as many vacancies as necessary to hire in expectation the desired number of workers next period.

The value of a firm with productivity z and employment n , $\Pi(n, z)$, is given by the following Bellman equation:

$$\Pi(n, z) = \max_v \left\{ y(n, z) - nw(n, z) - F^p - c(v) + \frac{1 - \delta}{1 + r} \Pi(n', z) \right\} \quad (3.3)$$

$$\text{subject to} \quad n' = n - sn + q(\theta)v$$

where firm's size n and time-invariant productivity z are the firm's state variables and the number of vacancies v is the firm's control variable.

Size of the firm next period n' is equal to the workers that stay with the firm $(1 - s)n$ plus the new hires $q(\theta)v$. Profits in any given period are given by firm's revenues $y(n, z)$ minus wage costs $nw(n, z)$, fixed cost of production F^p and the cost of posting vacancies $c(v)$. I allow for the fact that the wage can be a function of firm size and productivity.

The first-order condition of (3.3) characterizing the optimal vacancy-posting strategy of the firm, $v(n, z)$, is given by:

$$\frac{c'(v)}{q(\theta)} = \frac{1 - \delta}{1 + r} \frac{\partial \Pi(n', z)}{\partial n'} \quad (3.4)$$

The number of posted vacancies is chosen optimally, so that the discounted increase in the value of the firm as a result of hiring one extra worker is equal to the expected cost of hiring an extra worker.

Let us consider timing in the model. Wages are renegotiated every period. I assume that workers and firms cannot commit to future wages. Hence the choice of v_t and w_t takes place simultaneously, but they are independent. First, v_t has no impact on n_t and thus it has no impact on w_t . In other words, because hiring is a time-consuming process, employment is predetermined when wage bargaining takes place. The firm has an existing workforce at any given time and it is not able to adjust its size instantaneously. Second, w_t has no effect on v_t . v_t only depends on the expected w_{t+1} . This is because the number of vacancies is chosen in a forward-looking way. The firm at t knows how its choice of v_t affects n_{t+1} and thus w_{t+1} .

The firm takes into account the way in which its hiring decision today influences the size of its workforce and thus also its bargaining position the next period. Differentiating the maximised Bellman equation for firm value with respect to current employment n , using the envelope condition and the law of motion of employment:

$$\frac{\partial \Pi(n, z)}{\partial n} = \frac{\partial y(n, z)}{\partial n} - w(n, z) - \frac{\partial w(n, z)}{\partial n} n + \frac{1 - \delta}{1 + r} \frac{\partial \Pi(n', z)}{\partial n'} (1 - s) \quad (3.5)$$

Hence hiring a marginal worker not only means that the firm produces more output and that it has to pay a wage to another worker, but it may also affect the wage that the firm has to pay to its existing workers. I show in Section 3.2.4.1 that with individual wage bargaining the wage is decreasing in the size of the firm. Thus the firm can lower the wage that it faces by hiring more workers - there is wage externality from employment⁵.

The value of a worker employed at a firm with productivity z and employment n , $W(n, z)$,

⁵This is not a new result. E. Smith (1999) and Cahuc and Wasmer (2001) show that in a large firm search model with individual wage bargaining modelled as in Stole and Zwiebel (1996) firms tend to over-employ compared to the benchmark of a perfectly competitive labour market.

is given by:

$$W(n, z) = w(n, z) + \frac{1}{1+r} \left\{ (s + \delta - s\delta)U + (1 - s - \delta + s\delta)W(n', z) \right\} \quad (3.6)$$

$$\text{where} \quad n' = n - sn + q(\theta)v(n, z)$$

An employed worker receives wage $w(n, z)$ that can potentially depend on the size and productivity of his employer. The worker can lose his job when hit by a job separation shock s or when the firm that he is employed at is destroyed which takes place at rate δ . Otherwise the worker stays employed at the same firm next period where the firm's productivity is the same, but its size may change.

The value of an unemployed worker U is given by the following Bellman equation:

$$U = b + \frac{1}{1+r} \left\{ \theta q(\theta) E[W(n, z) \mid z \geq z^*, n] + (1 - \theta q(\theta))U \right\} \quad (3.7)$$

An unemployed worker receives b every period. This can be thought of as the value of leisure, the value of home production or the unemployment benefit. The probability that an unemployed worker becomes employed next period is given by the job-finding-rate $\theta q(\theta)$. The worker is randomly matched with a certain firm from the pool of vacancies. Therefore the value of an unemployed worker depends on the distribution of vacancies by firm size and productivity. This in turn depends on the joint distribution of firm size and productivity and on the intensity of vacancy posting of different kinds of firms. Only firms with productivity z greater than z^* are active and the largest firm size for a given z is the firm target size $n^*(z)$.

Thus the value of an unemployed worker is given by:

$$U = b + \frac{1}{1+r} \left\{ \theta q(\theta) \int_{z^*}^{\infty} \int_0^{n^*(z)} W(n, z) \frac{v(n, z) h(n, z)}{v_{tot}} dn dz + (1 - \theta q(\theta)) U \right\} \quad (3.8)$$

where v_{tot} is the total number of vacancies, $v(n, z)$ gives the number of vacancies posted by firms with size n and productivity z and $h(n, z)$ gives the number of firms with productivity z and size n . This joint distribution of firm productivity and size is given by:

$$h(n, z) = \frac{x g(n|z) f(z)}{1 - F(z^*)} \quad (3.9)$$

where x is the total number of firms, $f(z)$ and $F(z)$ are respectively the pdf and the cdf of the distribution from which a new firm draws its productivity, $g(n|z)$ gives the probability that firm size takes value n given that firm productivity is equal to z .

The value of an unemployed worker depends on labour market tightness θ which is given by:

$$\theta = \frac{v_{tot}}{u} = \frac{\int_{z^*}^{\infty} \int_0^{n^*(z)} v(n, z) h(n, z) dn dz}{N - \int_{z^*}^{\infty} \int_0^{n^*(z)} n h(n, z) dn dz} \quad (3.10)$$

3.2.3 Firm Entry

Firm Entry Condition: There is free entry in every period and thus it must hold in equilibrium that before observing the productivity, expected profits are equal to entry costs:

$$\int_{z^*}^{\infty} \Pi(0, z) f(z) dz = F^e \quad (3.11)$$

where F^e denotes fixed cost of entry. However, successful firm entry occurs only if the draw of z is above the threshold z^* .

Minimum Productivity Condition: Right after learning its productivity z , a firm decides to exit the market if it's value, the sum of discounted future profits, is negative. This defines

z^* , the productivity level where the firm is indifferent between staying and exiting.

$$\Pi(0, z^*) = 0 \quad (3.12)$$

Firms will generally make losses in the first periods of life as they are hiring intensely which is costly and they have to pay the fixed costs of production while they are producing below their optimal size. As firms become older and larger they hire less intensely and the fixed costs per unit of output decline. The fact that profits are rising in the firm's age seems to be a good fit for real-world firm dynamics. Discounted profits in the later periods have to be large enough to offset the losses in the early periods for a firm to have a positive value and to successfully enter the industry.

The level of firm entry every period $e > 0$ is implicitly determined by the firm entry condition (3.11). An increase in entry leads to a larger x , the mass of firms in the steady state, as can be seen from (3.13).

$$\underbrace{e(1 - F(z^*))}_{\text{firms successfully entering}} = \underbrace{x\delta}_{\text{firms exiting}} \quad (3.13)$$

$$x = \frac{e(1 - F(z^*))}{\delta}$$

As a consequence of a larger number of producing firms, more vacancies are posted and the aggregate employment is higher, increasing labour market tightness. This reduces the rate at which vacancies are filled and thus makes hiring more costly for firms. As a result the value of a new firm with no workers $\Pi(0, z)$ falls for every level of productivity z . Thus expected profits from entry fall in the level of entry. The left-hand-side of (3.11) is decreasing in e , while the right-hand-side is constant.

3.2.4 Wage Bargaining

3.2.4.1 Individual Wage Bargaining

The firm bargains with each individual worker separately as in Stole and Zwiebel (1996). Therefore each worker is treated as the marginal worker. Worker's outside option is the value of unemployment. Firm's outside option is the value of the firm without that worker. Therefore the worker's surplus is $W(n, z) - U$ and the firm's surplus is equal to the increase in the value of the firm from hiring the marginal worker, $\frac{\partial \Pi(n, z)}{\partial n}$. Due to symmetry the firm will pay the same wage to all its workers. Wage satisfies the following surplus-splitting rule:

$$(1 - \beta)(W(n, z) - U) = \beta \frac{\partial \Pi(n, z)}{\partial n} \quad (3.14)$$

where the parameter $\beta \in (0, 1)$ captures the bargaining power of the worker. Stole and Zwiebel (1996) show that condition (3.14) can be micro-founded either by cooperative or non-cooperative game theory.

Proposition 1 *The bargained wage, $w^I(n, z)$, solves the differential equation:*

$$w^I(n, z) = (1 - \beta) \frac{rU}{1 + r} + \beta \frac{\partial y(n, z)}{\partial n} - \beta \frac{\partial w(n, z)}{\partial n} n \quad (3.15)$$

The proof of Proposition 1 as well as proofs of all the Lemmas are in the Appendix. The expression above shows that, as in the standard search model, wage is increasing in the worker's outside option rU , in the marginal product of labour $\frac{\partial y(n, z)}{\partial n}$ and in worker bargaining power β . However, there is an additional term, $\frac{\partial w(n, z)}{\partial n} n$. This captures the fact that changes in the size of the firm's labour force have effect on the wage that it pays. Consider a firm's negotiations with a given worker. If these negotiations break down, the firm will have to pay its remaining workers a higher wage. This is because the fall in the number of workers implies that the marginal product of labour will be higher and thus each of the remaining workers is more valuable to the firm. The stronger is this effect, the more the firm loses from

a breakdown of negotiation with a particular worker and thus workers can obtain a higher wage.

Lemma 1 *The solution to the differential equation of Proposition 1 is given by:*

$$w^I(n, z) = (1 - \beta) \frac{rU}{1 + r} + \frac{\alpha\beta}{(\alpha\beta + 1 - \beta)} \frac{z}{n^{1-\alpha}} \quad (3.16)$$

I find that holding employment constant, wage is increasing in firm productivity. Additionally, holding firm productivity constant, wage is decreasing in employment. We can see this graphically on Figure 3.1⁶.

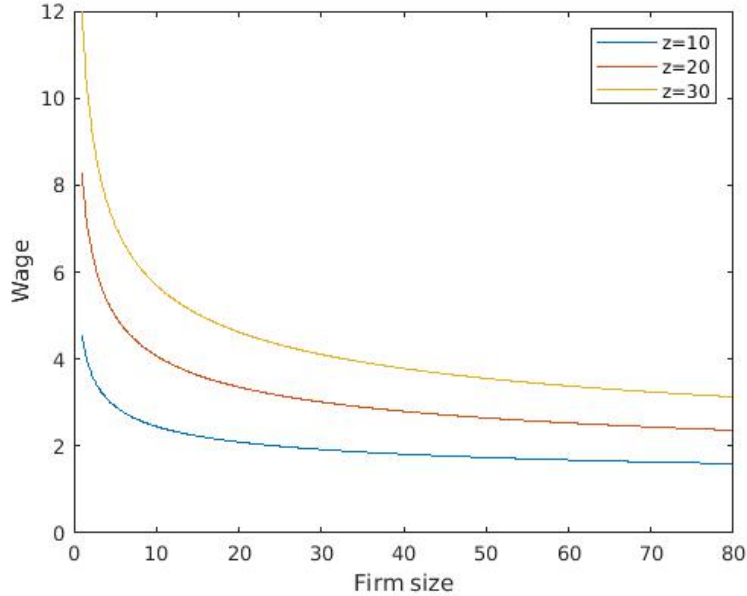


Figure 3.1: Wage for different permanent productivity and firm size levels

Corollary 1 *Under individual bargaining, as a firm grows towards its target size, the wage that it pays is declining. Therefore a young firm pays a wage premium compared to an old firm with the same time-invariant productivity z .*

A firm starts life with no workers. It then gradually grows in size via costly hiring. Firm

⁶Figures 3.1, 3.2(a) and 3.2(b) come from the model economy with individual wage bargaining that is calibrated to match US data moments and is discussed in Section 3.3.1.1.

productivity is constant over the life of the firm. Therefore the wage rate that the firm faces is declining over time as the firm is growing towards its target size. For firms with the same time-invariant productivity z , wage is decreasing in firm age because older firms are larger and are closer to the target size for that z . Thus young firms pay a wage premium.

This is supported by data. Schmieder (2013) uses linked employer-employee data from Germany and shows that controlling for establishment and worker fixed effects, wages are monotonically declining in firm age up to the age of 20 years when the effect disappears (equivalent of the target size in my model). Controlling for establishment time-invariant heterogeneity and worker composition, wages in establishments aged 1 year or less are on average 10 percent higher than in the establishments that are more than 20 years old. Schmieder (2013) also presents evidence that this difference is not a compensation for higher unemployment risk or slower future wage growth in young establishments. Babina et al. (2019) use data for the USA and show that while young firms on average pay lower wages, after controlling for firm and worker heterogeneity using firm and worker fixed effects, young firms actually pay more. They find a statistically significant young-firm pay premium that is monotonically decreasing with firm age. Specifically, firms aged one year or less pay 6.4 log point wage premium compared to firms older than 20 years.

Lemma 2 *Under individual wage bargaining the flow value of unemployment (reservation wage) is given by:*

$$rU^I = (1 + r)b + \theta q(\theta) \frac{\beta}{1 - \beta} \int_{z^*}^{\infty} \int_0^{n^*(z)} \frac{\partial \Pi(n, z)}{\partial n} \frac{v(n, z)h(n, z)}{v_{tot}} dn dz \quad (3.17)$$

The flow value of unemployment rU which acts as the reservation wage is increasing in the value of leisure b , in the job-finding-rate $\theta q(\theta)$ and in the size of the average surplus from employment relationship in the economy.

Lemma 3 *Under individual wage bargaining the target firm size $n^*(z)$ is implicitly defined*

by:

$$\frac{\lambda}{q(\theta)} + \frac{1-\delta}{r+\delta} \frac{1-\beta}{1+r} rU + \frac{\gamma s}{q^2(\theta)} n^* - \frac{1-\delta}{r+\delta} \frac{\alpha(1-\beta)}{\alpha\beta+1-\beta} z n^{*(\alpha-1)} = 0 \quad (3.18)$$

The firms with larger time-invariant productivity grow towards a larger target size; $n^*(z)$ is increasing in z .

Even with rent-sharing, more productive firms find it optimal to grow towards a larger size. This is simply the result of differences in time-invariant productivity between firms and decreasing returns to scale. This positive relationship is displayed on Figure 3.2(a).

We can see from Lemma 3 that faster decreasing returns to labour (lower α) lead to a smaller target size for a given z , holding everything else constant. The more costly is the vacancy posting (larger λ and γ) the smaller is the target size for a given z . The higher is the rate of exogenous job destruction (larger s), the lower is the target size for a given z . Higher labour market tightness θ increases the cost of hiring and thus lowers the target size for any z . Larger flow value of unemployment increases the outside option of workers in wage bargaining and pushes up wages and thus reduces the target size for each level of z .

Lemma 4 *Under individual bargaining the wage at the target firm size is given by:*

$$w^I(n^*(z), z) = \frac{rU}{1+r} + \frac{\beta}{1-\beta} \frac{r+\delta}{1-\delta} \frac{c' \left(\frac{sn^*(z)}{q(\theta)} \right)}{q(\theta)} \quad (3.19)$$

Thus, more productive firms pay higher wages at their respective target size.

We can see from Lemma 4 that the firm continues to grow until the wage that it pays equals the outside option of the worker, plus an extra term that is the result of the fact that workers are costly to replace. The term $\frac{c' \left(\frac{sn^*(z)}{q(\theta)} \right)}{q(\theta)}$ captures the cost of hiring the marginal worker when the firm is at its target size.

The intuition for the result in Lemma 4 is straightforward. A firm with a larger time-invariant productivity z will grow towards a larger target size, as shown in Lemma 3. Because

of its larger size, it will be losing more workers due to exogenous separations of matches. Thus it has to hire more workers every period just to stay at its target size. Given that hiring cost is convex, the marginal cost of hiring is higher for a larger firm. Thus the cost of replacing the marginal worker is higher for a firm with larger z . Under individual wage bargaining where each worker is treated as the marginal worker, this produces the outcome that at their respective target sizes the more productive firms pay higher wages. This can be seen graphically on Figure 3.2(b).

We can see from Lemma 4 that holding everything else constant, the wage at the target firm size is increasing in the rate of exogenous firm destruction δ . The wage is also increasing in the cost of vacancy posting (λ and γ) and in the rate of exogenous job destruction s . Furthermore, larger flow value of unemployment, rU , and worker bargaining power in individual negotiations, β , also each increase the wage at the target firm size.

Corollary 2 *Under individual bargaining, a high z firm faces a higher wage than a low z firm for all levels of n from 0 up to $n^*(z)$.*

The proof of this is straightforward. Each firm starts life with no workers and then gradually grows towards its target size. We can see from Lemma 1 and Figure 3.1 that for the same firm size, wages are increasing in permanent firm productivity z and that holding permanent firm productivity constant, wages are monotonically decreasing in firm size. A firm with a higher z grows towards a larger target size (Lemma 3), but even at the target size where its wage rate is the lowest it still faces a higher wage rate than a firm with a lower z at its respective target size (Lemma 4). Hence we can conclude that a firm with a higher permanent productivity z will face a higher wage rate along its entire growth path than a firm with a lower z .

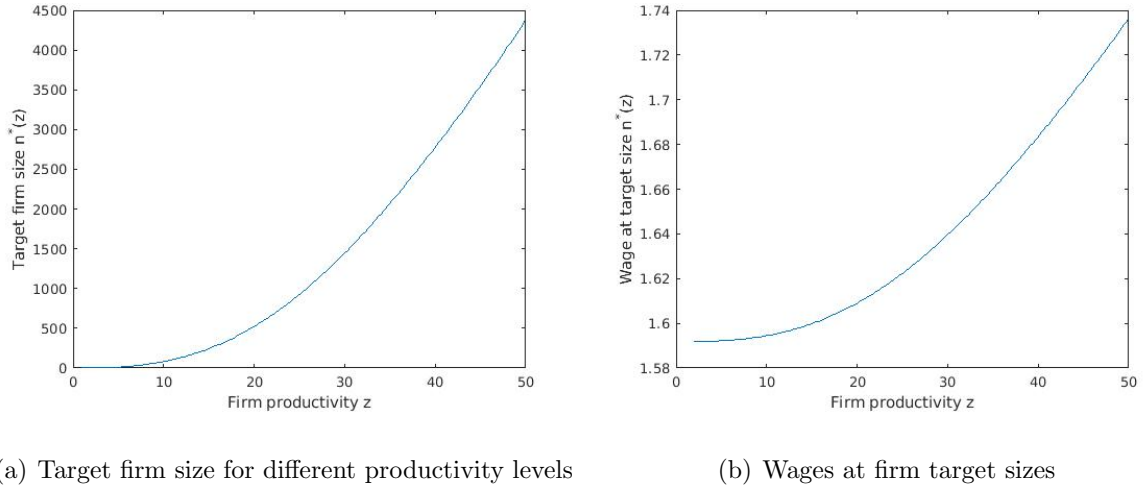


Figure 3.2: A numerical example of how target firm size and wage at the target size evolve with firm productivity.

3.2.4.2 Two-tier Collective Wage Bargaining

I assume that the model economy has a single sector. Therefore sector-wide and economy-wide wage setting are equivalent in this model⁷. Analysis of interactions between wage bargaining in different sectors is beyond the scope of this paper.

The wage under two-tier collective wage bargaining is given by:

$$w^C(n, z) = T + p(n, z) \quad (3.20)$$

Wage in the centralised case is composed of two parts: tariff wage T that is bargained at the sector level and applies to all the homogeneous workers; and wage premium $p(n, z)$ that is bargained at the firm-level and therefore depends on the firm's characteristics (size and productivity). This set up follows closely the real world where sector-level employer organisations and unions bargain over minimum wages for each occupation. Firms and firm-level unions are then free to agree to wages that are higher than the minimum. However, bargaining power of workers at the local level is limited by the fact that they cannot go on

⁷I could equivalently assume that there are Z identical sectors in the economy producing the single homogeneous good. Because of symmetry one could then focus on just one sector without loss of generality.

strike, only the sector-level union has a right to call a strike.

Timing: Every period, the sector-level bargaining over the tariff wage takes place before the firm-level bargaining over the wage premiums. Firm-level bargaining only takes place if the parties at the sector-level reach an agreement. Otherwise, there is a sector-wide strike and no bargaining at the firm-level (as can be seen from Figure 3.3).

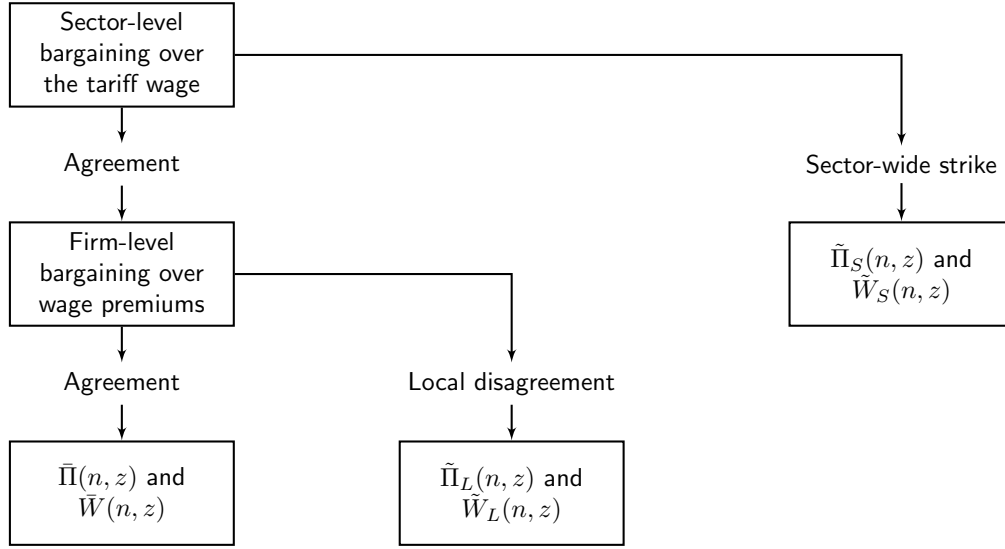


Figure 3.3: Two-tier collective wage bargaining

How are the wage premiums determined? If the bargaining parties at the sector-level reach an agreement and there is no sector-wide strike, then firm-level worker representatives bargain with owners of the firms over the wage premiums. This section of the model follows closely the framework of collective wage bargaining in the Scandinavian countries, especially in Sweden and Norway. At the firm level workers cannot go on a strike, but they can engage in work-to-rule actions where they follow work instructions in a pedantic manner (Barth, Moene, and Willumsen (2014)). Thus they reduce their effort by a small amount while still not breaking their contract and thus keeping their job. Workers can use this as a threat to extract wage premiums from the firm (Moene (1988), Moene, Wallerstein, and Hoel (1993)). During such local conflicts workers still receive the tariff wage T , but they no longer get the

premiums $p(n, z)$. Firms produce less output.

Individual wage bargaining is banned in the model, workers can only negotiate with the firm collectively via their representatives. However, each worker can choose to stay or leave the firm. Therefore in equilibrium all employed workers must be better off staying with their firm during a local conflict over pay rather than leaving and becoming unemployed. Later I present an equilibrium condition that must hold for this to be true and I restrict attention to only those combinations of parameter values where this condition holds.

Value of the firm in the case of an agreement:

$$\bar{\Pi}(n, z) = \max_{\bar{v} \geq 0} \left\{ y(n, z) - n(T + p) - F^p - c(\bar{v}) + \frac{1 - \delta}{1 + r} \Pi(n', z) \right\} \quad (3.21)$$

$$\text{subject to} \quad n' = n - sn + q(\theta)\bar{v}$$

Value of the firm in the case of a local disagreement:

$$\tilde{\Pi}_L(n, z) = \max_{\tilde{v} \geq 0} \left\{ \epsilon y(n, z) - nT - F^p - c(\tilde{v}) + \frac{1 - \delta}{1 + r} \Pi(n', z) \right\} \quad (3.22)$$

$$\text{subject to} \quad n' = n - sn + q(\theta)\tilde{v}$$

where

$$\Pi(n, z) = \max \left[\bar{\Pi}(n, z), \tilde{\Pi}_L(n, z) \right] = \bar{\Pi}(n, z) \quad (3.23)$$

and $\epsilon \in (0, 1)$. Thus during a local conflict workers reduce their level of effort and output is reduced by a fraction $(1 - \epsilon)$. The local disagreement over pay only lasts one period. At the beginning of the next period the firm and the workers come back to the negotiating table. A local conflict over pay has no permanent effects, it does not make disagreement next period more or less likely. Hence the value next period is the same in (3.21) and (3.22).

I assume that both the firm and the worker expect that in the next period an agreement

at sector level about the tariff wage will be reached and thus an industry-wide strike will be avoided. This expectation is correct in equilibrium. In the next period the firm and the worker can again either reach an agreement or not. However, there is no benefit to either party from the disagreement outcome, as the firm loses the fraction $(1-\epsilon)$ of its output and the worker loses the wage premium. Thus both sides expect to be in the agreement state $\bar{\Pi}(n, z)$ next period.

The first-order condition for vacancy posting (3.4) applied to this context gives:

$$\frac{c'(\bar{v})}{q(\theta)} = \frac{1-\delta}{1+r} \frac{\partial \Pi(n', z)}{\partial n'} \quad (3.24)$$

$$\frac{c'(\tilde{v})}{q(\theta)} = \frac{1-\delta}{1+r} \frac{\partial \Pi(n', z)}{\partial n'}$$

Vacancies are chosen in a forward-looking way such that the expected benefit from having one extra worker tomorrow is equal to the cost of hiring that extra worker. Given that a conflict over pay is temporary and does not change the expected state tomorrow, firms will post the same number of vacancies in both the agreement and the disagreement states.

$$\bar{v}(n, z) = \tilde{v}(n, z) = v(n, z) \quad (3.25)$$

The maximised value functions of the firm in the two states are thus given by:

$$\begin{aligned} \bar{\Pi}(n, z) &= y(n, z) - n(T + p) - F^p - c(v(n, z)) \\ &\quad + \frac{1-\delta}{1+r} \Pi(n - sn + q(\theta)v(n, z), z) \end{aligned} \quad (3.26)$$

$$\begin{aligned} \tilde{\Pi}_L(n, z) &= \epsilon y(n, z) - nT - F^p - c(v(n, z)) \\ &\quad + \frac{1-\delta}{1+r} \Pi(n - sn + q(\theta)v(n, z), z) \end{aligned}$$

Firm's gain from an agreement is given by: $\bar{\Pi}(n, z) - \tilde{\Pi}_L(n, z) = (1-\epsilon)y(n, z) - np$

Value of the worker in the case of an agreement:

$$\begin{aligned} \bar{W}(n, z) = T + p + \frac{1}{1+r} & \left\{ (s + \delta - s\delta)U \right. \\ & \left. + (1 - s - \delta + s\delta)W\left(n - sn + q(\theta)v(n, z), z\right) \right\} \end{aligned} \quad (3.27)$$

Value of the worker in the case of a local disagreement:

$$\begin{aligned} \tilde{W}_L(n, z) = T + \frac{1}{1+r} & \left\{ (s + \delta - s\delta)U \right. \\ & \left. + (1 - s - \delta + s\delta)W\left(n - sn + q(\theta)v(n, z), z\right) \right\} \end{aligned} \quad (3.28)$$

where

$$W(n, z) = \max \left[\bar{W}(n, z), \tilde{W}_L(n, z) \right] = \bar{W}(n, z) \quad (3.29)$$

Thus the surplus of each worker is given by: $\bar{W}(n, z) - \tilde{W}_L(n, z) = p$. I assume that all the workers at a particular firm are members of the firm-level union and that the union cares about all of its members equally. Therefore the union's gain from reaching an agreement (union surplus) is: np

The chosen wage premium maximizes the weighted product of the firm's and the union's surplus:

$$\max_{p \geq 0} \left(np \right)^\omega \left((1 - \epsilon)y(n, z) - np \right)^{1-\omega} \quad (3.30)$$

where $\omega \in (0, 1)$ represents bargaining power of workers at the firm-level. Thus the wage premium is given by:

$$p(n, z) = (1 - \epsilon)\omega \frac{y(n, z)}{n} \quad (3.31)$$

We can see that the wage premium is an increasing function of output per worker of the firm. Holding employment constant, wage premium is increasing in firm productivity. Holding firm productivity constant, wage premium is decreasing in employment. The effective bargaining

power of workers at the local level is captured by $(1 - \epsilon)\omega$, thus an increase in ω or a fall in ϵ imply greater wage premiums.

How is the tariff wage determined? The tariff wage T is the result of Nash bargaining between a union representing all the employed workers in the sector and an employer organisation representing all the firms in the sector. The threat point is the possibility of a sector-wide strike, for one period there is no production. Both parties take up the negotiation again in the next period. During the strike workers continue to be employed, but they do not receive the tariff wage or wage premiums. Instead they receive the value of leisure b . Firms cannot produce for one period, they are not paying out wages, but they still have to pay the fixed cost and the vacancy cost.

I do not assume that the outside option during sector-level wage bargaining is destruction of all employment relationships, i.e. all workers leaving firms or firms firing all the workers. This is because it would not be a credible threat. Employment relationships generate a joint surplus that glues the negotiating parties together (Hall and Milgrom (2008), Jimeno and Thomas (2013)). In the model hiring is a costly process and value of the firm is generally increasing in the size of its labour force. Losing all workers would mean that each firm would have to go through the slow and expensive process of re-hiring them and it would end up where it started. Workers receive the value of leisure under both a strike and unemployment. Thus a more realistic threat is that of a temporary strike. In equilibrium strikes never happen as the parties always find it beneficial to reach an agreement. However, the possibility of a strike enables workers to extract a share of the joint surplus.

Employer organisation is assumed to be maximising the stock market value (the value of all firms) in a steady state⁸. The employer organisation's surplus from an agreement is the sum of surpluses of all existing firms in the steady state:

$$\int_{z^*}^{\infty} \int_0^{n^*(z)} S^F(n, z) h(n, z) dn dz \quad (3.32)$$

⁸In future work I want to investigate stability of this steady state.

where $S^F(n, z)$ is the surplus from an agreement of a firm with size n and productivity z and $h(n, z)$ gives the measure of firms with employment n and productivity z in the steady state and is defined in (3.9).

Value of a firm in the case of an agreement:

$$\begin{aligned} \Pi(n, z) = \max \left[\bar{\Pi}(n, z), \tilde{\Pi}_L(n, z) \right] &= \bar{\Pi}(n, z) = y(n, z) - n(T + p(n, z)) - F^p - c(v(n, z)) \\ &+ \frac{1 - \delta}{1 + r} \Pi(n - sn + q(\theta)v(n, z), z) \end{aligned} \quad (3.33)$$

Value of a firm in the case of a sector-wide strike:

$$\tilde{\Pi}_S(n, z) = -F^p - c(v(n, z)) + \frac{1 - \delta}{1 + r} \Pi(n - sn + q(\theta)v(n, z), z) \quad (3.34)$$

First, I assume that the sector-level union and employer organisation expect that if an agreement about the tariff wage is reached then the firm-level negotiations about wage premiums will always end up in an agreement i.e. the value of the firm will be $\bar{\Pi}(n, z)$ and not $\tilde{\Pi}_L(n, z)$. This expectation is correct in equilibrium.

Second, I assume that the industry-wide strike is temporary and it has no effect on the likelihood of a strike next period. Therefore hiring is unaffected by a potential strike (the same argument as in the derivation of wage premiums).

Third, I assume that the sector-level negotiators are aware of the fact that the choice of T will be followed by bargaining over wage premiums at every firm and that they understand the structure of these negotiations and the size of the effective bargaining power of workers at local level. Therefore they can correctly predict the size of the wage premiums⁹.

⁹Because workers receive the tariff wage during both firm-level states: an agreement or conflict, the choice of T has no impact on the determination of wage premiums $p(n, z)$. The level of the tariff wage might affect what kind of firms (in terms of size and permanent productivity) exist in the steady state, but not the size of the wage premium for a particular firm size and productivity combination.

Finally, a firm's gain from an agreement is given by:

$$S^F(n, z) = \bar{\Pi}(n, z) - \tilde{\Pi}_S(n, z) = y(n, z) - n(T + p(n, z)) \quad (3.35)$$

Employer organisation's surplus is then:

$$\begin{aligned} & \int_{z^*}^{\infty} \int_0^{n^*(z)} \left(y(n, z) - n(T + p(n, z)) \right) h(n, z) \, dn \, dz \\ &= \int_{z^*}^{\infty} \int_0^{n^*(z)} \left(y(n, z) - nT - (1 - \epsilon)\omega y(n, z) \right) h(n, z) \, dn \, dz \\ &= \int_{z^*}^{\infty} \int_0^{n^*(z)} \left((1 - (1 - \epsilon)\omega) y(n, z) - nT \right) h(n, z) \, dn \, dz \\ &= (1 - (1 - \epsilon)\omega)Y - TL \end{aligned} \quad (3.36)$$

where Y is aggregate output and L is aggregate employment.

$$\begin{aligned} Y &= \int_{z^*}^{\infty} \int_0^{n^*(z)} y(n, z) h(n, z) \, dn \, dz \\ L &= \int_{z^*}^{\infty} \int_0^{n^*(z)} n h(n, z) \, dn \, dz \end{aligned} \quad (3.37)$$

I assume that all employed workers are members of the sector-level union and that the union cares about all of its members equally. Thus surplus of the sector-level union is the sum of surpluses of all employed workers in the steady state:

$$\int_{z^*}^{\infty} \int_0^{n^*(z)} S^W(n, z) n h(n, z) \, dn \, dz \quad (3.38)$$

Value of a worker in the case of an agreement:

$$\begin{aligned} \bar{W}(n, z) &= T + p(n, z) + \frac{1}{1 + r} \left\{ (s + \delta - s\delta)U \right. \\ &\quad \left. + (1 - s - \delta + s\delta)W(n - sn + q(\theta)v(n, z), z) \right\} \end{aligned} \quad (3.39)$$

Value of a worker in the case of a sector-wide strike:

$$\begin{aligned} \tilde{W}_S(n, z) = b + \frac{1}{1+r} & \left\{ (s + \delta - s\delta)U \right. \\ & \left. + (1 - s - \delta + s\delta)W\left(n - sn + q(\theta)v(n, z), z\right) \right\} \end{aligned} \quad (3.40)$$

Surplus from an agreement of a worker employed at firm with size n and productivity z :

$$S^W(n, z) = \bar{W}(n, z) - \tilde{W}_S(n, z) = T + p(n, z) - b \quad (3.41)$$

Hence surplus of the sector-wide union becomes:

$$\begin{aligned} & \int_{z^*}^{\infty} \int_0^{n^*(z)} \left(T + p(n, z) - b \right) n h(n, z) dn dz \\ = & \int_{z^*}^{\infty} \int_0^{n^*(z)} \left(T + (1 - \epsilon)\omega \frac{y(n, z)}{n} - b \right) n h(n, z) dn dz \\ & = TL + (1 - \epsilon)\omega Y - bL \end{aligned} \quad (3.42)$$

The tariff wage maximizes the weighted product of the sector-wide union's and the employer organisation's surplus:

$$\max_{T \geq 0} \left(TL + (1 - \epsilon)\omega Y - bL \right)^{\mu} \left((1 - (1 - \epsilon)\omega)Y - TL \right)^{1-\mu} \quad (3.43)$$

where $\mu \in (0, 1)$ represents bargaining power of the sector-level union. I assume that the sector-wide union and the employer organisation take the aggregate output Y and aggregate employment L as given. Thus they do not internalize the effect that the choice of the tariff wage has on these variables. The resulting tariff wage T is given by:

$$T = (1 - \mu)b + \left(\mu - (1 - \epsilon)\omega \right) \frac{Y}{L} \quad (3.44)$$

Thus we can see that holding $\frac{Y}{L}$ constant, the tariff wage is increasing in the worker

power at sector-level, μ , and it is decreasing in worker power at firm-level, $(1 - \epsilon)\omega$. Larger wage premiums imply a smaller tariff wage, holding everything else constant. As long as $\mu > (1 - \epsilon)\omega$ the tariff wage is increasing in the average output per worker of the sector. It is also increasing in the worker outside option, b .

Admittedly, the fact that the sector-level union and the employer organisation are taking aggregate employment and output as given is a strong assumption. In a more realistic setup the sector-level negotiators would take into account how the choice of the tariff wage affects aggregate outcomes. A higher tariff wage reduces firm's profits in the current period as well as the value of firms. As a result some firms might have negative value and choose to close down. The threshold firm productivity level, z^* , will be higher. This will affect aggregate employment and output.

In the case that sector-level negotiators internalise the effects of the wage setting on aggregate outcomes the tariff wage is given by:

$$T^f = \underset{\text{argmax}}{\left(TL(T) + (1 - \epsilon)\omega Y(T) - bL(T) \right)^\mu \left((1 - (1 - \epsilon)\omega)Y(T) - TL(T) \right)^{1-\mu}} \quad (3.45)$$

In the remainder of the chapter I use the simpler expression (3.44) for two reasons. First, it greatly reduces the computational complexity of solving the model. Second, my main interest in this chapter is to explore the aggregate effects of reducing wage dispersion across firms while keeping the average wage level the same. The exact way in which the tariff wage is determined affects the wage level, but not the dispersion. Therefore it does not affect the main findings of this chapter¹⁰.

Lets come back to the issue of the correct outside option during firm-level wage bargaining. The expression for wage premium in (3.31) was derived assuming that the credible threat of employed workers is to reduce their effort and stay with the firm rather than to permanently separate from the firm. In order for this to hold it must be that in equilibrium

¹⁰However, I do plan to incorporate (3.45) into the model's analysis in future work.

the value of being an employed worker during local conflict over pay, $\tilde{W}_L(n, z)$, at any existing firm is always larger than the value of unemployment U . Thus the following has to hold:

$$\tilde{W}_L(n, z) \geq U \quad \forall n, z \quad (3.46)$$

This will hold as long as even at the lowest-paying firm workers prefer to stay with the firm during a local dispute over pay rather than leave, thus as long as:

$$\tilde{W}_L(n^*(z^*), z^*) \geq U \quad (3.47)$$

First, wages are increasing in firm productivity z . Second, for a given productivity level, wages are decreasing in firm size. So for a certain z , wage is the lowest at the target size for that z , $n^*(z)$. Therefore, the lowest wage and thus the lowest value of an employed worker will be at the firms that have the lowest productivity level in the steady state, z^* , and have reached their target size $n^*(z^*)$.

When there is complete centralisation of wage bargaining, $(1 - \epsilon)\omega = 0$ and $w^C = T$, all firms are paying only the tariff wage. Hence wages are completely equalised across firms. In this case workers will accept employment when matched with a firm as long as the single wage rate w^C is larger than the value of leisure, b . Given that workers receive the value of leisure during an industry-wide strike and $\mu \in (0, 1)$, $w^C > b$ and thus workers always accept employment. In this case all firms pay the same wage given by $w^C = (1 - \mu)b + \mu \frac{Y}{L}$, so a worker has no reason to reject a job offer and keep looking for a better match.

However, when $\epsilon < 1$ and $\omega > 0$, there are wage premiums being paid and wages vary across firms. Then a worker matched with a low-wage firm might want to leave that firm, become unemployed and try to match with a better firm. The fact that workers can not only go on a strike, but can also leave their firms then puts a limit on how much wage dispersion there can be in the steady state. For the two-tier collective wage bargaining above to be credible it must be that even a worker at the lowest-paying firm is better off than being

unemployed.

I deal with this issue in the following way. While calibrating the model I check that the condition (3.46) holds. I restrict attention to only those combinations of parameters and the resulting set of equilibria where (3.46) is satisfied.

In Nash bargaining each party always gets at least their outside option. Given that $\omega > 0$ workers also receive some share of the surplus. So if workers prefer staying with the firm during a local conflict over pay then it must be true that they are strictly better off being employed at the firm, working and receiving wage premiums, than being unemployed.

$$W(n, z) > U \quad \forall n, z \quad (3.48)$$

Hence workers always accept employment when matched with a firm.

Lemma 5 *Wage under two-tier collective bargaining is given by:*

$$\begin{aligned} w^C(n, z) &= T + p(n, z) \\ &= T + (1 - \epsilon)\omega \frac{y(n, z)}{n} \\ &= (1 - \mu)b + \left(\mu - (1 - \epsilon)\omega\right) \frac{Y}{L} + (1 - \epsilon)\omega \frac{z}{n^{1-\alpha}} \end{aligned} \quad (3.49)$$

The model is able to capture different degrees of centralisation of collective wage bargaining. When $\epsilon = 1$ or $\omega = 0$ there are no wage premiums being paid and $w^C = T = (1 - \mu)b + \mu \frac{Y}{L}$, we have complete centralisation, a single wage. When the effective worker bargaining power at firm-level is positive, $(1 - \epsilon)\omega > 0$, then wage premiums are being paid and the wage under collective bargaining varies with firm size and permanent firm productivity.

The idea behind centralisation of wage bargaining is to put restrictions on industrial actions at the firm-level, i.e. to limit the ability of workers to reduce their level of effort and thus lower output while remaining employed. In the model greater centralisation of wage bargaining is represented by a fall in the effective bargaining power of workers at the local

level, $(1 - \epsilon)\omega$. As a result the component of the wage that depends on firm characteristics, the wage premium, is reduced in size. However, the base rate paid to all the homogeneous workers, the tariff wage, is likely to rise. This is because the sector-level negotiations where the tariff wage is determined take place first and the negotiators take into account the size of the wage premiums. Holding aggregate employment and output constant, a reduction in $(1 - \epsilon)\omega$ (smaller wage premiums) leads to a bigger joint surplus to be shared at the sector level, as can be seen from (3.43). Intuitively, a fall in $(1 - \epsilon)\omega$ also reduces wage dispersion across firms.

Decentralisation of wage bargaining has the opposite effects. A rise in $(1 - \epsilon)\omega$ increases wage premiums and tends to reduce the tariff wage. Wages vary more with firm characteristics and thus the wage dispersion among homogeneous workers grows.

As $\epsilon \rightarrow 0$ the two-tier collective bargaining model becomes very similar to a model of firm-level unions (in the Appendix), because workers are able to reduce their level of effort to zero which is equivalent to a firm-specific strike. Under firm-level unions $\epsilon = 0$ and $T=0$, collective bargaining is completely decentralised in the sense that there are no negotiations at sector-level and instead firm-level unions are able to call a strike during which no production takes place at that particular firm for one period (the level of effort falls to zero) and no wages are paid. Therefore this general model of two-tier collective bargaining nests the model of firm-level unions and the model of bargaining only at the sector-level (complete centralisation) as two extreme cases.

Corollary 3 *Under two-tier collective wage bargaining with $(1 - \epsilon)\omega > 0$, as a firm grows towards its target size, the wage that it pays is declining. Therefore a young firm pays a wage premium compared to an old firm with the same time-invariant productivity z .*

The logic here is exactly the same as for Corollary 1 in the case of individual wage bargaining. Wage under both individual wage bargaining and two-tier collective bargaining with $(1 - \epsilon)\omega > 0$ is an increasing function of the firm's output per worker. Given decreasing returns to scale, output per worker and the wage are decreasing in firm size. Firm productivity

is constant over the life of the firm. Therefore the wage rate that the firm faces is declining over time as the firm is growing towards its target size. For firms with the same permanent productivity z , wage is decreasing in firm age because older firms are larger. Thus young firms pay a wage premium.

Lemma 6 *Under two-tier collective bargaining the target firm size $n^*(z)$ is implicitly defined by:*

$$\frac{\lambda}{q(\theta)} + \frac{\gamma s}{q(\theta)^2} n^* + \frac{1-\delta}{r+\delta} T - \frac{(1-\delta)(1-\omega(1-\epsilon))\alpha}{r+\delta} z(n^*)^{\alpha-1} = 0 \quad (3.50)$$

The firms with larger time-invariant productivity grow towards a larger target size; $n^(z)$ is increasing in z .*

Similarly as under individual bargaining, the firm target size n^* is increasing in the level of time-invariant firm productivity z . The combination of decreasing returns to scale and productivity heterogeneity means that more productive firms choose to stop growing at a larger size than less productive firms.

Lemma 7 *Under two-tier collective wage bargaining with $(1-\epsilon)\omega > 0$, the wage at the target firm size is given by:*

$$w^C(n^*(z), z) = \frac{\alpha - (1-\alpha)(1-\epsilon)\omega}{\alpha - \alpha(1-\epsilon)\omega} T + \frac{(1-\epsilon)\omega}{\alpha - \alpha(1-\epsilon)\omega} \frac{r+\delta}{1-\delta} \frac{c'\left(\frac{sn^*(z)}{q(\theta)}\right)}{q(\theta)} \quad (3.51)$$

Thus, firms with larger permanent productivity z pay higher wages at their respective target size.

In the section on individual wage bargaining I show that firms with higher permanent productivity z pay higher wages at their respective target sizes (Lemma 4). Lemma 7 shows that the same thing holds under two-tier collective wage bargaining with $(1-\epsilon)\omega > 0$. The intuition for this finding is the following. A firm with a larger time-invariant productivity z will grow towards a larger target size, as shown in Lemma 6. Because of its larger size,

it will be losing more workers due to exogenous separations of matches. Therefore it has to hire more workers every period just to stay at its target size. Given that hiring cost is convex, the marginal and average cost of hiring is higher for a larger firm. Therefore firms with high permanent productivity will grow to a smaller size than they would if recruitment costs were linear. When looking at firms that are at their respective target size, the ones with larger z have higher output per worker and they pay higher wages.

Corollary 4 *Under two-tier collective wage bargaining with $(1 - \epsilon)\omega > 0$, a high z firm faces a higher wage than a low z firm for all levels of n from 0 up to $n^*(z)$.*

This is the same finding as for the case of individual wage bargaining. The proof of Corollary 4 is straightforward. We can see from Lemma 5 that for the same firm size n , wages are increasing in permanent productivity z and that holding z constant, wages are decreasing in firm size. A firm with a larger z grows towards a larger target size (Lemma 6), but even at that target size where its wage rate is the lowest it still faces a higher wage rate than a firm with a lower z at its respective target size (Lemma 7). Hence we can conclude that a firm with a higher permanent productivity z will face a higher wage rate along its entire growth path than a firm with a lower z .

3.2.4.3 Comparing Individual and Collective Wage Bargaining

Let us now contrast the wage under the two bargaining regimes.

$$\begin{aligned} w^I(n, z) &= (1 - \beta) \frac{rU}{1 + r} + \frac{\alpha\beta}{(\alpha\beta + 1 - \beta)} \underbrace{\frac{z}{n^{1-\alpha}}}_{APL} \\ w^C(n, z) &= (1 - \mu)b + \left(\mu - (1 - \epsilon)\omega\right) \frac{Y}{L} + (1 - \epsilon)\omega \underbrace{\frac{z}{n^{1-\alpha}}}_{APL} \end{aligned} \tag{3.52}$$

We can see that under both individual wage bargaining and two-tier collective wage bargaining where $(1 - \epsilon)\omega > 0$, the wage is a function of firm size and productivity. Thus there is rent-sharing and homogeneous workers are paid different wages at different firms under both

regimes. However, I will next show that under a reasonable parametrisation wages under collective bargaining will respond to the firm's average product of labour less than under individual bargaining.

$$\frac{\partial w^I(n, z)}{\partial APL} = \frac{\alpha\beta}{(\alpha\beta + 1 - \beta)} \quad \frac{\partial w^C(n, z)}{\partial APL} = (1 - \epsilon)\omega \quad (3.53)$$

We can see from (3.53) that the derivative of individually-bargained wage with respect to average product of labour of the firm is a function of α and β . The derivative is increasing in β and decreasing in α . Hence wages under individual bargaining vary more with output per worker of the firm when bargaining power of workers in the individual negotiations is higher and when returns to scale decline more slowly.

The derivative of wage under collective bargaining with respect to average product of labour is decreasing in ϵ and increasing in ω . Thus wages under collective bargaining vary more with output per worker of the firm when workers can reduce their effort by a greater proportion during a disagreement about wage premiums and when the share of the joint surplus at firm-level that goes to workers is higher.

Wages under collective bargaining will respond to the firm's average product of labour less than under individual bargaining as long as the following holds.

$$(1 - \epsilon)\omega < \frac{\alpha\beta}{(\alpha\beta + 1 - \beta)} \quad (3.54)$$

Empirical studies find estimates of α , the elasticity of output with respect to labour, around 0.64¹¹. For β let us take the value from Shimer (2005) and set it equal to 0.72. Then we obtain the following condition for the effective bargaining power of workers at the local level.

$$(1 - \epsilon)\omega < 0.622 \quad (3.55)$$

¹¹Whether targeting aggregate labour share or looking at estimates of plant-level labor demand models the value of α is around 0.64 (Cooper, Haltiwanger, and Willis (2004), Elsby and Michaels (2013)).

The fraction of the normal effort that workers deliver during a local dispute over pay, ϵ , is likely to be very close to 1, because workers cannot go on a strike and they still have to perform all the tasks that are specifically written in their contracts. Say that workers reduce their effort by 10% during a dispute with their firm and thus $\epsilon = 0.9$. In that case even if the bargaining power of workers at the firm level (their share of the surplus) was extremely high, say $\omega = 0.99$, then $(1 - \epsilon)\omega = 0.099 < 0.622$. Therefore we can conclude that as long as firm-level unions cannot organise a strike, their effective bargaining power is limited and the relationship between output per worker and the wage will be weaker under collective bargaining than under individual bargaining.

As $\epsilon \rightarrow 0$ workers are able to reduce their level of effort down to zero during a dispute over wage premiums which is equivalent to a firm-level strike. Now the effective bargaining power of workers at firm-level is given by $(1 - \epsilon)\omega = \omega$. Using (3.55) we can see that wages vary less with output per worker under collective bargaining than under individual bargaining as long as $\omega < 0.622$. This requires that $\omega < \beta = 0.72$, so the share of the joint surplus acquired by workers is lower when workers bargain collectively than when they negotiate individually. This is unrealistic. Hence it is quite likely that the relationship between wages and output per worker is stronger under firm-level collective bargaining where workers can threaten a strike than under individual bargaining. This highlights the importance of centralisation of collective bargaining, i.e. putting limitations on industrial actions at firm-level.

3.2.5 Equilibrium

Definition 1 A tuple $\{\Pi(n, z), v(n, z), w^I(n, z), rU^I, z^*, \theta, h(n, z) \text{ and } e\}$ is a **steady state equilibrium under individual wage bargaining** if the following holds:

- The value of a firm $\Pi(n, z)$ satisfies (3.3) and the vacancy function $v(n, z)$ is given by the FOC of the firm optimisation problem (3.4).
- The productivity cutoff z^* is given by the Minimum Productivity Condition (3.12).

- Wage equation $w^I(n, z)$ is given by Lemma 1 and the flow value of unemployment rU^I is given by Lemma 2.
- The joint distribution of firm size and productivity $h(n, z)$ is given by (3.9).
- The labour market tightness θ is given by (3.10).
- The level of entry $e > 0$ is implicitly determined by the firm entry condition (3.11).

Definition 2 A tuple $\{\Pi(n, z), v(n, z), w^C(n, z), z^*, \theta, h(n, z) \text{ and } e\}$ is a **steady state equilibrium under two-tier collective wage bargaining** if the following holds:

- The value of a firm $\Pi(n, z)$ satisfies (3.3) and the vacancy function $v(n, z)$ is given by the FOC of the firm optimisation problem (3.4).
- The productivity cutoff z^* is given by the Minimum Productivity Condition (3.12).
- Wage equation $w^C(n, z)$ is given by Lemma 5.
- The joint distribution of firm size and productivity $h(n, z)$ is given by (3.9).
- The labour market tightness θ is given by (3.10).
- The level of entry $e > 0$ is implicitly determined by the firm entry condition (3.11).

3.2.5.1 Income Accounting in the Model

In this section I define some aggregate objects that I will be using later to compare a calibrated economy with individual bargaining with one that contains collective wage bargaining. In the model households act as both workers and investors, supplying labour and owning firms. Thus they receive income from two sources: wages and firm profits.

Total wage bill is given by:

$$WB = \int_{z^*}^{\infty} \int_0^{n^*(z)} w(n, z) n h(n, z) dn dz \quad (3.56)$$

Total firm profits are given by:

$$\bar{\pi} = \int_{z^*}^{\infty} \int_0^{n^*(z)} \pi(n, z) h(n, z) dn dz \quad (3.57)$$

where $\pi(n, z) = y(n, z) - nw(n, z) - F^p - c(v(n, z))$.

However, households have to create just enough new firms every period to offset the exogenous firm destruction at rate δ and to keep the number of firms in the steady state constant. The size of the investment into creation of new firms is given by: $e F^e$.

I define *Total value added* of the economy as the units of the final good that can be consumed by households. This is equal to the income that the households receive, net of the cost of firm creation.

$$VA = WB + \bar{\pi} - eF^e \quad (3.58)$$

Firm entry costs F^e , firm fixed costs F^p , and firm recruitment costs $c(v)$ are all expressed in terms of units of the final good. I assume that resources spent on these three costs are wasted i.e. these units of the final good cannot be consumed. If I assumed that resources spent on firm entry count towards total value added then from the point of view of a social planner that is maximising total value added the ideal equilibrium would be one with infinite firm entry. This is because there would be no cost to firm entry, only benefit. Similarly, if units of the final good spent on firm fixed costs counted towards total value added then there would be no cost (in terms of value added) to having a larger stock of firms in the economy. Finally, if resources spent on recruitment counted towards total value added then there would be no cost to having extremely high number of vacancies and incredibly high market tightness. Therefore total value added in the model is equal to total production minus total firm entry costs, total firm fixed costs and total search (recruitment) costs.

Total value added is given by:

$$VA = Y - e F^e - x F^p - \int_{z^*}^{\infty} \int_0^{n^*(z)} c(v(n, z)) h(n, z) dn dz \quad (3.59)$$

where Y is the total production of the final good defined by (3.37), eF^e gives total firm entry costs, xF^p gives total fixed costs and $\int_{z^*}^{\infty} \int_0^{n^*(z)} c(v(n, z)) h(n, z) dn dz$ are total recruitment (search) costs.

Total value of firms (the value of the stock market) is equal to:

$$\bar{\Pi} = \int_{z^*}^{\infty} \int_0^{n^*(z)} \Pi(n, z) h(n, z) dn dz \quad (3.60)$$

3.3 Analysis

In this section I solve the model numerically and analyse the implications of different wage setting institutions for wage dispersion among homogeneous workers and for aggregate outcomes. I present a model with individual wage bargaining that is calibrated to match US data moments, as well as a model with two-tier collective wage bargaining calibrated to match Swedish data moments. I compare the two cases and also run three counterfactual experiments.

First, I apply completely centralised sector-level wage bargaining to the model economy calibrated to US data moments. Hence I compare aggregate outcomes under individually-bargained wages with the case of a single wage rate that is set at sector level. I do this comparison for different levels of bargaining power of the sector-level union. However, I pay special attention to the case where the single sector-level wage is equal to the average wage under individual bargaining. In this way I investigate the aggregate effects of removing all wage dispersion across firms while keeping the mean wage constant. Second, I take the model economy with individual wage bargaining that is calibrated to the USA and I simultaneously reduce bargaining power of workers in individual negotiations and increase the value of leisure and thus the worker outside option. However, I focus on such combinations of the two parameters where the mean wage remains the same. In this way I am reducing wage dispersion among homogeneous workers while keeping the average wage level the same.

Third, I investigate the effects of changes in the effective worker bargaining power at firm-level in the calibrated economy with two-tier collective bargaining. Hence I am analysing the effects of varying the degree of centralisation of wage setting in a Swedish-style economy. In all three cases my primary focus is to explore the implications of mean-preserving wage compression for aggregate outcomes¹².

A detailed description of the numerical methods of solving the model is in the Appendix, the case of individual wage bargaining is discussed in Section 3.5.3.1, the case of two-tier collective wage bargaining is in Section 3.5.3.2 and the case of sector-only collective bargaining is in Section 3.5.3.3. Here I present the functional form assumptions that I use.

I assume that the aggregate matching function is Cobb-Douglas with efficiency parameter m_0 and elasticity parameter ϵ .

$$m(u, v_{tot}) = m_0 u^\epsilon (v_{tot})^{1-\epsilon} \quad (3.61)$$

The underlying distribution from which a new firm draws its permanent productivity is Pareto with shape parameter k and minimum value z_{min} . Its cumulative distribution function is given by:

$$F(z) = 1 - \left(\frac{z_{min}}{z} \right)^k \quad (3.62)$$

As outlined in Section 3.2.1 the production function is Cobb-Douglas given by $y(n, z) = zn^\alpha$ where $\alpha \in (0, 1)$ captures the decreasing returns to scale. The cost of posting vacancies is given by $c(v) = \lambda v + \frac{1}{2}\gamma v^2$ where λ captures the linear part of the recruitment cost and γ captures the convex part.

¹²It is important to separate changes in the level of wages to changes in the dispersion.

3.3.1 Calibration

3.3.1.1 Model with individual wage bargaining

The time period is a month. The model with individual wage bargaining is calibrated to the USA. The first set of parameters either come from empirical studies or have a direct target. Their values and sources are displayed in Table 3.1. The elasticity of output with respect to labour, the parameter α , is set equal to 0.64 to match the estimates of plant-level labor demand models (Cooper, Haltiwanger, and Willis (2004)). The interest rate is 0.417% monthly or 5% annually (Shimer (2005)). Total separation rate at monthly frequency is 3.33% in the US (Shimer (2005))¹³. Furthermore, one sixth of separations are due to establishment closure (Davis, J.C. Haltiwanger, and Schuh (1996)). Therefore the exogenous match destruction rate s is 2.83% and the exogenous firm destruction rate δ is 0.547%. The elasticity of substitution in the matching function, parameter ϵ , is set as 0.72 (Shimer (2005)). I target monthly job finding rate of 45% and labour market tightness of 0.72 (Shimer (2005))¹⁴. This implies m_0 , the technology parameter in the aggregate matching function, equal to 0.4934¹⁵. N , the size of the labour force is normalised to 100. The minimum value of z , z_{min} is normalised to 1 (as in Acemoglu and Hawkins (2014)). For the reasons of computational complexity I set the linear part of the recruitment cost, λ , equal to zero. This means I have one fewer parameter to estimate.

The second group of parameters are jointly calibrated using the method of simulated moments. The parameters are chosen optimally in order to minimize the loss function which is a weighted average of squared proportional deviations of model-generated moments from the data moments. There are 6 parameters and 11 targets. The jointly estimated parameters are γ , which captures the degree of convexity in recruitment cost, F^e , fixed cost of firm entry, F^p , fixed cost of production, b , the value of leisure, k , the shape parameter of the Pareto firm

¹³The figure is 10% quarterly and it is an average for the period 1951-2003.

¹⁴These are long-term averages for the USA based on the period 1951-2003.

¹⁵Job finding rate = $\frac{m(u, v_{tot})}{u} = m_0 u^{\epsilon-1} v_{tot}^{1-\epsilon} = m_0 \theta^{1-\epsilon}$. We know the job finding rate, θ and ϵ and thus we can find m_0 .

Symbol	Meaning	Value	Target
α	the extent of DRS in production function	0.64	empirical estimates
r	interest rate	0.00417	5% annual rate, Shimer(2005)
s	exogenous match destruction rate	0.0283	total separation rate in US is 10% quarterly and ...
δ	exogenous firm destruction rate	0.005466	1/6 of separations are due to establishment closure
ϵ	elasticity of substitution in $m(u, \bar{v})$	0.72	Shimer (2005)
m_0	technology parameter in $m(u, \bar{v})$	0.4934	job finding rate=45%, $\theta=0.72$ in the US
N	size of the labour force	100	normalisation
z_{min}	minimum value of $f(z)$	1	normalisation
λ	the linear part of recruitment cost	0	simplifying assumption

Table 3.1: Model parameters at monthly frequency (USA)

Symbol	Meaning	Calibrated Value
γ	captures the degree of convexity in recruitment cost	0.055
F^e	fixed costs of firm entry	315.711
F^p	fixed costs of production	0.381
b	value of leisure	0.850
k	the shape parameter of $f(z)$	1.917
β	worker bargaining power	0.481

Table 3.2: Parameters calibrated jointly at monthly frequency (USA)

productivity distribution and finally β , worker bargaining power. Their calibrated values are shown in Table 3.2.

The joint targets at monthly frequency are displayed in Table 3.3. First, as mentioned above, I target labour market tightness equal to 0.72. Second, I target average firm size of 24.03 which comes from the 2016 issue of the Longitudinal Business Database of the Census Bureau. Third, I target average per-worker hiring costs in the model economy to be equal to 102% of the average monthly wage. The average cost-per-hire of US companies is \$4,129 according to a 2016 report by the Society for Human Resource Management¹⁶. The National Average Wage Index of the Social Security Administration was \$48,642 in 2016. I take this as a measure of annual mean wage in the USA. Thus I find that the average cost-per-hire in

¹⁶This is based on surveys of companies in 2015-2016. Other organisations have reported similar figures for the average hiring costs.

Target	Value	Source
labour market tightness	0.72	Shimer(2005)
average employment per firm	24.03	Longitudinal Business Database
per-worker hiring costs as % of mean monthly wage	102%	Society for Human Resource Management
elasticity of wages w.r.t. firm size	0.021	Bloom et al (2018)
average wage difference first year of the firm vs at target size	6.61%	Babina et al (2019)
firm size distribution (6 points)		Longitudinal Business Database

Table 3.3: The joint targets at monthly frequency (USA)

the US is 8.49% of the annual wage or 102% of the monthly wage¹⁷.

My fourth target is that the elasticity of wages with respect to firm size is equal to 0.021 i.e. doubling of firm size is on average associated with 2.1% higher wage. I take this estimate from Bloom et al. (2018) who use US social security data for the period 2007–2013. Crucially, they control for the differences in worker quality between firms using worker fixed effects. This is important because in my model there are no differences in worker quality across firms. As discussed in Section 3.2.4.1 the model with individual wage bargaining predicts that firms will face higher wages at the beginning of their life than when they are older. In order to put a reasonable limit on this dimension of the model-generated wage dispersion I introduce my fifth target. On average in the model economy the difference between the average wage of a firm in the first year of its life and its wage at the target size should be equal to 6.61%. This estimate comes from Babina et al. (2019) who find using US data that after controlling for firm and worker time-invariant heterogeneity firms aged one year or less pay 6.4 log point wage premium compared to firms older than 20 years. Finally, I target the US firm size distribution. Longitudinal Business Database provides me with 6 points of the firm size distribution to target.

Let us consider the fit of the calibration. Table 3.4 presents a comparison of the model-generated moments and data moments. The model does a very good job of fitting labour

¹⁷In Elsby and Michaels (2013) the vacancy cost is targeted to match per-worker hiring cost equal to just 42% of monthly worker pay. However, they follow Silva and Toledo (2009) who cite an estimate of the cost of posting vacancies from the human resources consulting firm, the Saratoga Institute. My target includes other recruitment costs, not just the cost of posting vacancies.

Target	Model Moment	Data Moment
labour market tightness	0.68	0.72
average employment per firm	22.99	24.03
per-worker hiring costs as % of mean monthly wage	97.29%	102.00%
elasticity of wages w.r.t. firm size	0.006	0.021
average wage difference first year vs at target size	7.84%	6.61%

Table 3.4: Fit of the Calibration (USA)

market tightness, average firm size and per-worker hiring cost. Market tightness is 0.68 in the model and 0.72 in the data. Average firm size is 22.99 in the model and 24.03 in the data. Per-worker hiring cost as a percentage of mean monthly wage is 97.29% in the model and 102.00% in the data. The model does also quite a good job fitting the average difference in wages that a firm is paying in the first year of its life compared to when it is at its target size. This young-firm wage premium is 7.84% in the model and 6.61% in the data.

However, the model fails to match the elasticity of wages with respect to firm size. The elasticity is 0.021 in the data, but only 0.006 in the model. The model is capable of generating larger firm size wage premium, but only at the expense of substantially overshooting the target for the young firm pay premium. It seems that the model in its current form is incapable of meeting both targets, only one of them¹⁸. The model's fit of the firm size distribution is displayed in Figure 3.4. We can see that compared to the empirical distribution the model generates too many firms with size of 1-4 workers and too few firms with sizes 5-9 and 10-19. For larger firm size categories the model does a good job¹⁹.

Table 3.5 presents some untargeted moments. Standard deviation of log wages across homogeneous workers is 0.041 in the model. The empirical estimates of log wage dispersion in the US accounted for by firm heterogeneity after controlling for worker heterogeneity with fixed effects range from 0.024 to 0.113²⁰. It is very encouraging that the model-generated

¹⁸For this reason I plan on adding shocks to firm-level productivity to the model. I believe that this would improve the model's ability to match the data moments.

¹⁹Except that the model generates slightly more of the very large firms (100 workers and more) than the empirical distribution.

²⁰The empirical estimates of the share of annual earnings variance in the USA that can be explained by firm policies (firm fixed effects) range from 3% to 14%. Studies using the AKM approach (worker and firm

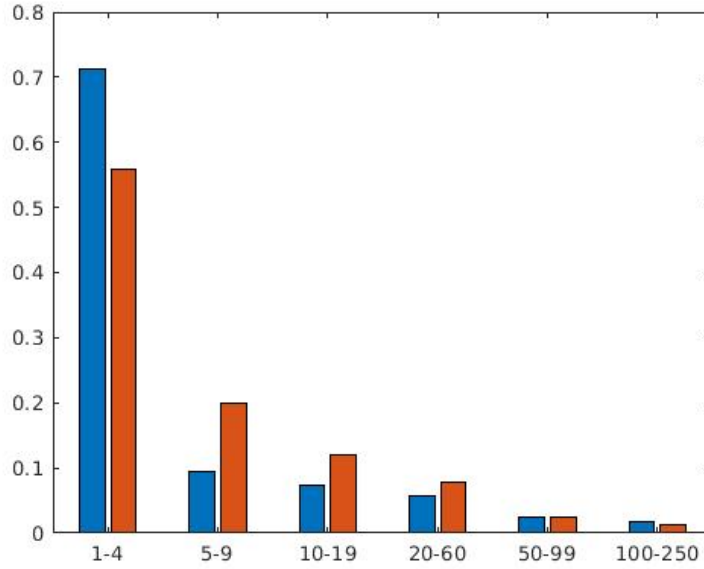


Figure 3.4: Fit of the US firm size distribution (blue:model, red:data)

wage dispersion that is driven by differences in firm characteristics via rent-sharing is well within the range of empirical estimates without it being targeted at all. Another untargeted moment that I examine is the ratio of the value of leisure b that unemployed workers receive every period to the average wage in the economy. This ratio is equal to 0.52 in the model. The US replacement ratio in other search and matching models and in empirical studies is typically between 0.4 and 0.6. However, in these cases b is usually thought of as an unemployment benefit. Therefore the b / mean wage ratio in my model is perhaps too large, but it is not unreasonable.

fixed effects model, Abowd, Kramarz, and Margolis (1999)) report the following share of earnings dispersion accounted for by firm policies in the USA: 12% Song et al. (2019), 14% Sorkin (2018) and 9% Lamadon, Mogstad, and Setzler (2019). However, it has been demonstrated that the AKM method suffers from limited mobility bias, there are not enough conditionally independent observations for each worker and firm. This leads to an upward bias in the estimate of the variance of firm fixed effects and a downward bias in the estimate of covariance of worker and firm fixed effects (Andrews et al. (2008), Lamadon, Mogstad, and Setzler (2019)). Alternative approaches that account for the limited mobility bias provide much smaller estimates of the US earnings dispersion accounted for by firm heterogeneity: 3% in Lamadon, Mogstad, and Setzler (2019), 5% in Andrews et al. (2008) and Kline, Saggio, and Sølvssten (2019). All of the studies above used annual earnings whereas my model generates dispersion of wages. I make the assumption that the share of wage dispersion that is due to firm heterogeneity is the same as the equivalent share for annual earnings. Using data from the Luxemburg Income Study I calculate that the standard deviation of log gross hourly wages in the USA in 2014 was 0.808. Combining this figure with the highest and the lowest percentages reported above gives me an interval that is reported in Table 3.5.

Target	Model Moment	Data Moment
standard deviation of log hourly wages	0.041	0.024-0.113
b / average wage	0.52	0.4-0.6

Table 3.5: Untargeted Moments (USA)

3.3.1.2 Model with two-tier collective bargaining

The time period is again a month. The model with two-tier collective bargaining is calibrated to Sweden. The first set of parameters, displayed in Table 3.6, come from empirical studies or can be identified individually using some data moment(s). I set the exogenous firm destruction rate δ equal to 0.16% per month. I obtain the figure by dividing the number of people employed in exiting firms by the total employment in all active firms in Sweden and calculating average for the period 2008-2017 (using Eurostat's Structural Business Statistics database). Knowing the average unemployment rate in Sweden (7.37%) and the average monthly job finding rate (12.41%) for the period 2005-2020 based on data from Statistics Sweden I use the Beveridge curve to calculate the implied monthly total separation rate (0.99%). Given the value of δ and of the total separation rate, I find the exogenous match destruction rate s to be equal to 0.83% at monthly frequency. Knowing the average labour market tightness in Sweden (0.203) and the average monthly job finding rate in the period 2005-2020, I find that the implied value of the efficiency parameter in the matching function, m_0 , is 0.194. Finally, I keep the extent of decreasing returns to scale α , the interest rate r , the elasticity of substitution in the aggregate matching function ϵ , the size of the labour force N , minimum value of firm productivity distribution z_{min} and the linear part of the recruitment cost λ the same as in the case of individual wage bargaining.

The second group of parameters are calibrated jointly in order to minimize the difference between model moments and selected data moments. However, I also ensure that the condition (3.46) holds, i.e. in equilibrium the value of being an employed worker during local conflict over pay, $\tilde{W}_L(n, z)$, at any existing firm is always larger than the value of unemployment U . Hence I am minimizing the gap between model and data moments subject to the

Symbol	Meaning	Value	Target
α	the extent of DRS in production function	0.64	empirical estimates
r	interest rate	0.00417	5% annual rate, Shimer(2005)
s	exogenous match destruction rate	0.0083	total separation rate in Sweden is 0.987% monthly
δ	exogenous firm destruction rate	0.0016	Eurostat's Structural Business Statistics database
ϵ	elasticity of substitution in $m(u, \bar{v})$	0.72	Shimer (2005)
m_0	technology parameter in $m(u, \bar{v})$	0.1938	monthly job finding rate=12.41%, $\theta= 0.2033$ in Sweden
N	size of the labour force	100	normalisation
z_{min}	minimum value of $f(z)$	1	normalisation
λ	the linear part of recruitment cost	0	simplifying assumption

Table 3.6: Model parameters at monthly frequency (Sweden)

Symbol	Meaning	Calibrated Value
γ	captures the degree of convexity in recruitment cost	1.125
F^e	fixed costs of firm entry	121.936
F^p	fixed costs of production	2.166
b	value of leisure	1.235
k	the shape parameter of $f(z)$	2.079
μ	sector-level union's bargaining power	0.546
$(1 - \epsilon)\omega$	effective bargaining power of workers at firm-level	0.115

Table 3.7: Parameters calibrated jointly at monthly frequency (Sweden)

fact that the credibility of local bargaining condition holds. There are 7 parameters and 9 joint targets. The jointly estimated parameters are γ , the degree of convexity in recruitment cost, F^e , fixed cost of firm entry, F^p , fixed cost of production, b , the value of leisure, k , the shape parameter of the Pareto firm productivity distribution, μ , bargaining power of sector-level union and finally $(1 - \epsilon)\omega$, the effective bargaining power of workers at the firm level. Their calibrated values are shown in Table 3.7.

Table 3.8 shows the joint targets at monthly frequency. First, I target labour market tightness equal to 0.203 which is calculated with Statistics Sweden data for the period 2005-2020. Second, I target average firm size equal to 17.85 which is calculated by dividing total employment in all firms in Sweden by the total number of firms (data comes from the Structural Business Statistics database). Third, I think of the fixed costs that firms face

Target	Value	Source
labour market tightness	0.203	Statistics Sweden
average employment per firm	17.85	Eurostat's Structural Business Statistics database
fixed costs of production as % of average firm revenue	3.2%	OECD (2001)
per-worker hiring costs as % of mean monthly wage	102%	Society for Human Resource Management
elasticity of wages w.r.t. firm size	0.013	Arai (2003)
average wage difference first year of the firm vs at target size	6.61%	Babina et al (2019)
firm size distribution (3 points)		Eurostat's Structural Business Statistics database.

Table 3.8: The joint targets at monthly frequency (Sweden)

every period as reflecting administrative costs. I target aggregate fixed costs in the economy to be 3.2% of aggregate firm revenue. This is based on OECD (2001) report which finds that administrative costs of regulatory compliance have very large fixed cost component and it estimates that in Sweden a typical SME firm faces regulatory costs equal to 3.2% of its revenue²¹. Next, I target average per-worker hiring costs to be equal to 102% of mean monthly wage which is exactly the same as in the case of individual wage bargaining. Hence I assume that typical hiring costs do not significantly vary between the USA and Sweden. I make this assumption because I have not been able to find an equivalent empirical estimate for Sweden. Next, I target the elasticity of wages with respect to firm size to be equal to 0.013 (this estimate for Sweden comes from Arai (2003)). This is much smaller than for the US. My sixth target is that on average in the model economy the difference between the average wage of a firm in the first year of its life and its wage at the target size should be equal to 6.61%. Here again no empirical estimate exists for Sweden and thus I use the US estimate, so that I can put a realistic limit on the size of this kind of wage dispersion in the model. Finally, I target Swedish firm size distribution. Eurostat's Structural Business Statistics database provides me with 3 points of the firm size distribution to target.

Let us now consider fit of the calibration. A comparison of the model-generated and data moments is presented in Table 3.9. We can see that the model does a brilliant job of matching all the moments except the elasticity of wages with respect to firm size. The

²¹Unfortunately, I have not been able to find an equivalent estimate for the US.

Target	Model Moment	Data Moment
labour market tightness	0.206	0.203
average employment per firm	17.18	17.85
fixed costs of production as % of average firm revenue	2.8%	3.2%
per-worker hiring costs as % of mean monthly wage	105.53%	102.00%
elasticity of wages w.r.t. firm size	0.0007	0.0130
average wage difference first year vs at target size	6.37%	6.61%

Table 3.9: Fit of the Calibration (Sweden)

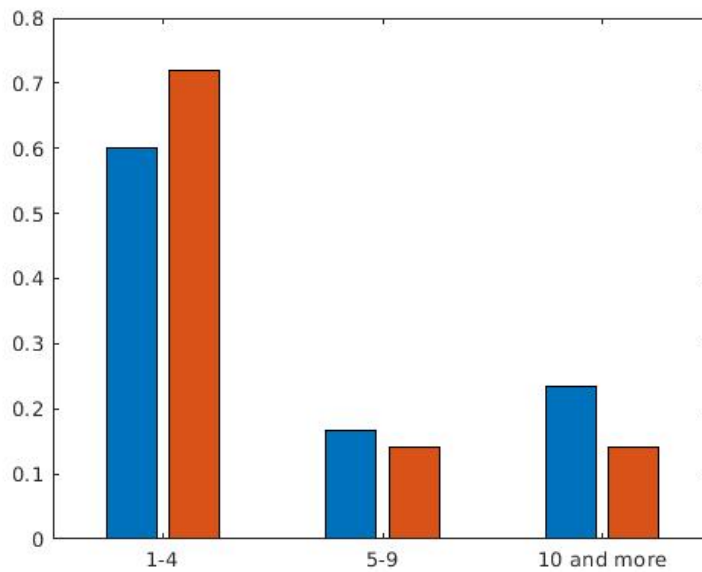


Figure 3.5: Fit of the Swedish firm size distribution (blue:model, red:data)

calibrated economy has market tightness of 0.206, average size of firms is 17.18, the total fixed costs are equal to 2.8% of total firm revenue, per-worker hiring costs are 105% of mean monthly wage and on average firms pay 6.37% young firm wage premium. However, doubling firm size is only associated with 0.07% rise in the wage rate, whereas the empirical target implies 1.3% rise in the wage rate. Therefore the model again fails to match the stylized fact that larger firms generally pay higher wages. Finally, the model fits the Swedish firm size distribution reasonably well (Figure 3.5).

Table 3.10 displays some model and data moments that were not targeted in the cali-

bration. Standard deviation of log wages across homogeneous workers is 0.013 in the model. The empirical estimate of log wage dispersion accounted for by firm heterogeneity after controlling for worker heterogeneity in Sweden is 0.008²². Therefore the model-generated wage dispersion is very close to the empirical estimate without it being targeted at all. The second moment that I examine is the ratio of the value of leisure b to the average wage in the economy. This ratio is 0.41 in the calibrated model with two-tier collective wage bargaining which is a reasonable value.

Target	Model Moment	Data Moment
standard deviation of log hourly wages	0.013	0.008
b / average wage	0.41	0.4-0.6

Table 3.10: Untargeted Moments (Sweden)

3.3.2 Results

Let us now compare the aggregate outcomes (defined in section 3.2.5.1) under individual and two-tier collective wage bargaining. Just to reiterate, I ensure that in the the model economy with two-tier collective bargaining the condition (3.46) holds and thus the value of being an employed worker during local conflict over pay, $\tilde{W}_L(n, z)$, at any existing firm is larger than the value of unemployment U . The first column in Table 3.11 shows outcomes for the model economy with individual wage bargaining calibrated to the USA, whereas the second column displays outcomes for the model economy with two-tier collective wage bargaining calibrated to Sweden. First, we can see that total value added in the collective bargaining economy is more than twice as high as in the individual bargaining economy. The size of labour force

²²To the best of my knowledge Bonhomme, Lamadon, and Manresa (2019) is the only study that estimates the share of annual earnings that are accounted for by firm heterogeneity (while controlling for worker unobservable heterogeneity) in Sweden. They find that 2.6% of variance of log earnings is accounted for by firm fixed effects. Their method accounts for limited mobility bias and generally produces estimates of the firm share of earnings dispersion that are on the lower end. Using Structure of Earnings Survey I find that in 2014 the standard deviation of log gross hourly wages in Sweden was 0.308. Assuming that the share of wage dispersion accounted for by firm effects is the same as the share of earnings dispersion and combining the two estimates above I obtain the figure in Table 3.10.

is the same in both cases and thus value added (or consumption) per capita is more than twice as high in the collective bargaining economy. Average wage is also almost twice as high in the collective bargaining economy than in the US-style economy. Unemployment rates are approximately equal while wage dispersion among homogeneous workers in the collective bargaining economy is less than a third of the level in the individual bargaining economy. Furthermore, the threshold level of firm productivity z^* is about 2.5 times higher and the amount of firm entry every period is more than three times larger in the collective bargaining economy. In the collective bargaining case there are more firms which are on average smaller and output per worker (labour productivity) is about twice as large as in the individual bargaining case. Total wage bill, total firm profits and total value of firms (the value of the stock market) are twice, three times and four times larger, respectively, in the collective bargaining case. Let us now return to the question of why total value added is so much larger in the collective bargaining case. The economy calibrated to Swedish data moments produces both higher total production and overall higher costs (entry, recruitment, fixed) that are assumed to be a deadweight loss. However, the increase in total production is larger than in the costs and thus it has larger total value added.

From the above comparison it looks like the Swedish-style model economy with two-tier collective wage bargaining produces clearly superior aggregate outcomes compared to individual bargaining economy calibrated to the US. However, it is very important to note that here we are varying both the type of wage bargaining and the model parameters given that the two cases were calibrated to different targets. Hence this is not a fair comparison of the relative merits of the two wage setting institutions. In order to better understand the aggregate effects of centralisation of wage bargaining I present a counterfactual experiment in the next section where I apply sector-level wage bargaining to an economy calibrated to the US data moments.

Lets now explore the nature of wage dispersion in the model economy with individual wage bargaining. I draw a random sample of 10 000 firms from the model and plot the relationship

Wage-setting	Individual (USA)	Two-tier collective (Sweden)
Total value added	171.66	367.94
Average wage	1.647	3.006
Unemployment rate	7.06%	7.35%
Market tightness	0.679	0.206
Standard deviation of log wages	0.041	0.013
Firm productivity cutoff z^*	1.933	5.170
Firm entry	0.078	0.265
Successful entry	0.022	0.009
Measure of firms	4.042	5.392
Output per worker	2.206	4.482
Average size of firms	22.994	17.183
Total production	205.03	415.22
Total wage bill	153.10	278.49
Total firm profits	43.26	121.77
Total cost of entry	24.70	32.32
Total search cost	7.13	3.27
Total fixed costs	1.54	11.68
Total value of firms	4 927	21 561

Table 3.11: USA vs Sweden: Individual bargaining vs Two-tier collective wage bargaining

between log wages and log permanent productivity, log firm size and the relative distance from the target size in Figures 3.6(b) - 3.6(d). We can see that firms with higher permanent productivity do generally pay higher wages, but there is a very large wage variance for any given firm productivity level caused by differences in firm age and thus firms being different distance from the target size for that level of productivity (Figure 3.6(b)). We can also see that in any given cross-section most firms are at or very near their target size²³ (as the density on the plots is the highest there) and that wages at target sizes are increasing in firm productivity. There is also an overall positive association between firm size and wages

²³Even though in a cross-section only very few firms are far from their target size, from time-series perspective every firm starts life with no workers and only gradually grows towards its target size and therefore high wages at the beginning of the firms life have a large effect on its profitability and its value.

(Figure 3.6(c)). This is the result of two opposing forces. On one hand, firms with higher permanent productivity grow towards larger target sizes and at those sizes more productive (larger) firms pay higher wages. On the other hand, firms that are young and far from their target size and thus generally smaller pay a wage premium. This is shown on Figure 3.6(d) where relative distance is defined as the ratio of the current firm size to its target size.

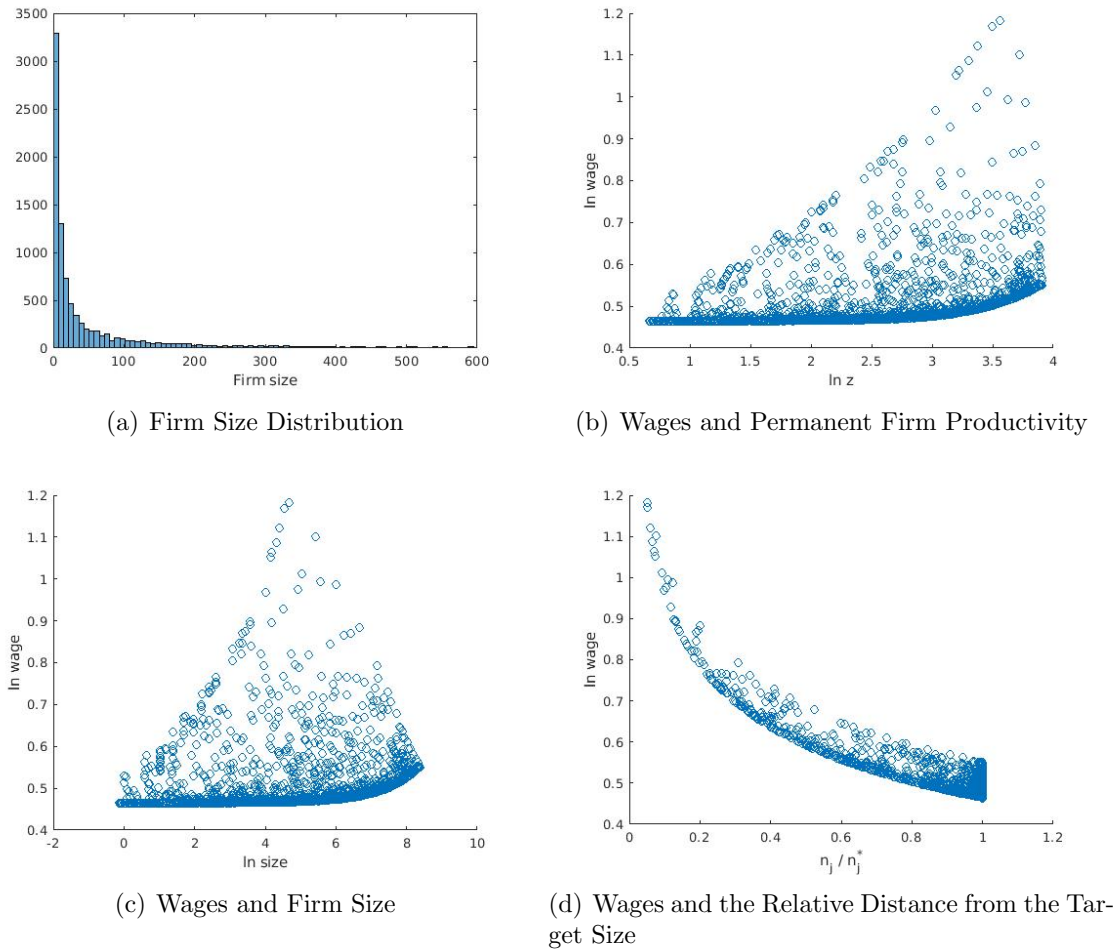


Figure 3.6: Wages and Firm Size Under Individual Bargaining

Next I explore the nature of wage dispersion in the model economy with two-tier collective wage bargaining. We can see that the relationship between permanent productivity and wages is much weaker than in the model economy with individual wage bargaining calibrated to the USA (Figure 3.7(b)). The same thing is true for the relationship between firm size and

wages (Figure 3.7(c)). This is in line with the fact that the calibrated model is very far from the target for the elasticity of wages with respect to firm size (Table 3.9). The individual bargaining economy also undershoots this target, but to a much smaller degree. The weak association between firm size and wages is driven mainly by the fact that at target size, wages vary less with firm productivity than in the individual bargaining economy (the dense area in Figures 3.7(b) and 3.7(c) is less steep than in Figures 3.6(b) and 3.6(c)). However, wages are still declining as firms grow towards their target sizes (Figure 3.7(d)).

Finally, we can see from Figures 3.6(a) and 3.7(a) that firm size distribution has a Pareto shape in both model economies with many small firms and very few large firms. This is mainly the result of assuming that firm productivity distribution is Pareto.

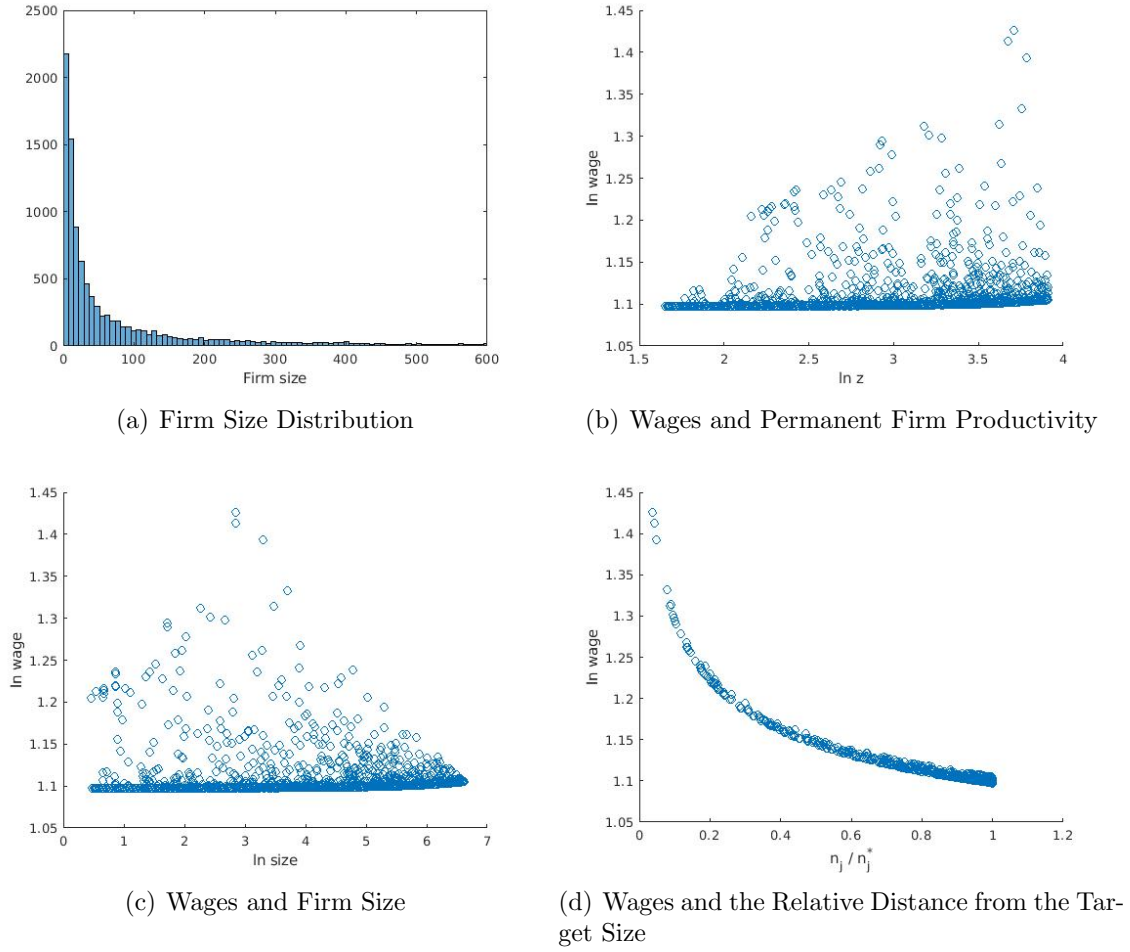


Figure 3.7: Wages and Firm Size Under Two-tier Collective Bargaining

3.3.3 Experiment 1: Applying sector-level wage setting to the USA

In this section I run a counterfactual experiment of applying completely centralised sector-level collective wage bargaining to the USA i.e. there is a single sector-wide wage rate paid out to all the homogeneous workers. I take the model with complete centralisation of collective wage bargaining where $(1 - \epsilon)\omega = 0$ and $w^C = T = (1 - \mu)b + \mu \frac{Y}{L}$. I solve the model for various levels of μ , the bargaining power of sector-level union, while all the other parameters come from the calibration of an economy with individual wage bargaining to the US data moments. I compare aggregate outcomes under the two different wage setting

regimes: individual and sector-level. My main focus is on total value added defined by (3.59), as it captures the total amount of the good produced that can be consumed. As discussed in Section 3.2.5.1 I assume that the costs of entry, firm fixed costs and search (recruitment) costs are a deadweight loss, the units of the final good spent on these expenses cannot be consumed. Therefore total value added in the model is equal to total production minus total firm entry costs, total firm fixed costs and total search (recruitment) costs.

What are the effects of equalising wages across firms? First, there is a *Firm entry effect*. Wage costs in the beginning of the firm's life are reduced and therefore expected profits from firm entry rise. The bigger is the discounting of future profits (the higher is r and δ), the stronger is this effect. More entry raises the number of firms in the steady state as well as total employment and production. This increases total value added. On the other hand, greater costs of firm entry and greater fixed costs of production (because there are more firms) lower total value added. Thus the overall effect on total value added is a priori ambiguous.

Second, there is a *Firm selection effect*. Switching from individually-bargained wages to sector-level bargaining has two opposing effects on firm selection. On one hand, because wages are no longer a function of the firm's marginal product of labour, firms do not face very high wages when they have few employees. This means that they save on wage costs in the early periods of their life and that they can afford to grow more slowly, saving on convex recruitment costs. Given that firms discount future profits, changes in their profitability in the early periods can have large effects on the value of firms. This boost in firm values enables even less productive firms to survive in the marketplace - see *Minimum Productivity Condition* (3.12). Thus the threshold firm productivity level, z^* , might fall as selection of firms is less strict.

On the other hand, under individual wage bargaining, a firm with higher permanent productivity faces higher wages than a firm with lower permanent productivity along its entire growth path (for all levels of firm size up to each firm's target size). Equalisation of

wages across firms that comes with sector-level wage bargaining lowers wage costs of firms with high permanent productivity and increases their profitability relative to firms with lower permanent productivity. This enforces stricter selection of firms with a higher z^* , minimum level of productivity necessary for survival.

Ex ante it is unclear which of the two opposing effects will dominate. The overall effect on firm selection depends on the level of the wage set under sector-level bargaining. The higher it is, the higher will be z^* . The level of the common wage rate in turn depends on sector-level union's bargaining power μ . If z^* does increase then average firm productivity will be higher and this contributes towards larger total value added. The greater selection pressures on firms would then result in reallocation of output and employment from less to more productive producers and in higher average labour productivity.

Third, there is a *Firm size effect*. Given that under complete centralisation of wage setting the wage is fixed and not decreasing in firm size, firms no longer have an incentive to over-hire in order to push down wages. This lowers the average size of firms. Due to decreasing returns to scale in production a lower average firm size raises the average output per worker in the economy. Here total value added rises for two reasons: because firms are smaller they save resources on (convex) recruitment costs and the average output per worker is higher.

The above is a qualitative analysis of the channels through which compression of wages across firms might affect aggregate outcomes. The general equilibrium effects of centralisation of wage bargaining can only be found numerically.

The first column in Table 3.12 shows aggregate outcomes of the model economy with individual wage bargaining calibrated to the USA. Columns 2-4 show aggregate outcomes of this model economy with completely centralised sector-level wage bargaining for different levels of μ , union bargaining power. The second column displays outcomes in the case where I set μ such that the average wage in the economy is the same as under individual wage bargaining. I do this because I am interested in the effects of reducing wage dispersion among

homogeneous workers (in this case down to 0) while keeping the average wage level the same. Comparing the first two columns, we can see that sector bargaining results in significantly higher total value added (171.66 vs 192.32) as well as substantially lower unemployment (7.06% vs 4.97%) while keeping the mean wage the same (1.647 vs 1.649).

Let us dig deeper to understand this headline result. We can see that there is a very powerful *Firm entry effect*. There is twice as much firm entry (0.078 vs 0.160) and twice as many active firms (4.042 vs 8.693) under sector bargaining compared to individual bargaining. We can also see that the threshold productivity z^* is actually lower under sector bargaining (1.933 vs 1.881). Hence the overall *Firm selection effect* is to reduce selection pressures²⁴. The reduction in wages faced by firms in the beginning of their life and the resulting boost to the value (the sum of expected discounted profits) of firms of all productivity levels seem to outweigh the fact that both high and low permanent productivity firms now face the same wage. We can also see very strong *Firm size effect*. Firms are on average smaller under sector bargaining (22.99 vs 10.93) which results in higher average output per worker (2.206 vs 2.804) because of decreasing returns to scale. Total production of the final good is significantly higher under collective bargaining (205.03 vs 266.51). This is because output per worker is higher and there are more employed workers than in the baseline case. While total wage bill is only slightly larger in the sector-level bargaining case (153.10 vs 155.45), total firm profits are twice as large (43.26 vs 87.31). Given the massive gap in total profits it is unsurprising that the total value of firms (essentially the value of the stock market) is twice as large under sector bargaining than in the baseline economy (4 927 vs 10 264). Due to the amount of entry and the mass of firms being about twice as large, the total costs of entry and the total fixed costs are also twice as large as in the baseline case. Total recruitment costs are almost three times larger in the collective bargaining case. This is mainly driven by the fact that the labour market tightness is almost four times larger in the sector bargaining case. Despite much larger costs (entry, fixed and recruitment) the

²⁴However, this result may be sensitive to the fact that the model fails to meet the target on the elasticity of wages with respect to firm size.

Wage-setting	Individual-level	Sector-level	Sector-level	Sector-level
Union bargaining power μ	-	0.405	0.440	0.490
Average wage	1.647	1.649	1.737	1.888
Total value added	171.66	192.32	203.82	206.09
Unemployment rate	7.06%	4.97%	5.67%	11.91%
Market tightness	0.679	2.579	1.569	0.087
Standard deviation of log wages	0.041	0	0	0
Firm productivity cutoff z^*	1.933	1.881	1.965	2.043
Firm entry	0.078	0.160	0.164	0.165
Successful entry	0.022	0.048	0.045	0.042
Measure of firms	4.042	8.693	8.201	7.679
Output per worker	2.206	2.804	2.871	2.969
Average size of firms	22.994	10.932	11.503	11.472
Total production	205.03	266.51	270.88	261.55
Total wage bill	153.10	155.45	163.85	166.30
Total firm profits	43.26	87.31	91.68	92.00
Total cost of entry	24.70	50.44	51.72	52.21
Total search cost	7.13	20.44	12.23	0.33
Total fixed costs	1.54	3.31	3.12	2.92
Total value of firms	4 927	10 264	10 232	9 657

Table 3.12: Applying sector-level bargaining to a model economy calibrated to the US

increase in the total production is so large that the model economy with sector bargaining (where the average wage is the same as in the baseline case) still generates larger total value added. Hence it seems that reducing wage dispersion while keeping the average wage level the same results in an improvement in welfare (as measured by the units of the final good that can be consumed).

Let us now consider the effects of increasing the bargaining power of the industry-level union, μ . Comparing columns 2-4 we can see that quite intuitively a higher μ results in significantly higher average wage in the economy, but also in higher unemployment rate. The relationship between μ and unemployment seems to be convex where initially the unemploy-

ment rate rises only slightly, but for higher values of μ it rises much sharply. Interestingly, a higher μ also results in higher total value added. However, the relationship seems to be concave in the sense that increases in μ have larger effects on total value added for lower levels of μ than for higher ones. This suggests that there probably exists a value of $\mu \in (0, 1)$ that maximizes total the value added in this economy, holding all other parameters constant.

Let us now look at the other aggregate effects of raising μ in order to better understand why higher μ can deliver larger total value added. By increasing the tariff wage, a rise in union bargaining power enforces tougher firm selection and results in larger productivity cutoff z^* . As a result average firm productivity is larger. Interestingly, the amount of firm entry stays approximately the same. Firm entry depends on expected profits from entry which are decreasing in both the tariff wage and in labour market tightness. Higher μ raises the tariff wage, but it also reduces the market tightness. It seems that the two effects broadly offset each other so that the expected profits from firm entry and thus the amount of firm entry are unaffected. However, the amount of firms successfully entering (firms that enter and draw z above z^* and thus stay and produce) is falling in μ . This is because z^* is monotonically increasing in μ . As a consequence of declines in successful entry, the stock of firms declines in μ as well. Average size of firms first rises and then falls in μ . Output per worker is increasing in μ , this is most likely the consequence of higher average productivity level of surviving firms.

Total production first rises and then falls in μ . Increases in the union bargaining power have two opposing effects on the total production. On one hand, a higher μ leads to a higher average productivity of firms. On the other hand, a higher μ leads to lower employment. Thus each employed worker is more productive, but there are fewer employed workers. Initially, the first effect dominates, but for higher values of μ the second effect dominates.

Total wage bill and total firm profits are increasing in μ , but at a decreasing rate. Total value of firms first rises, but then slightly declines. Total costs of entry map the development of firm entry and are broadly stable. Total fixed costs follow the trajectory of the stock of

firms and thus they are decreasing. Finally, total search costs decline massively as μ rises. This is because the labour market tightness also declines very sharply in μ .

Total value added is equal to total production minus the three types of costs. While total search and fixed costs monotonically decline in μ , total production first rises and then falls in μ . This gives rise to a positive, but concave relationship between total value added and the union's bargaining power μ .

Lets come back to the issue of why sector-level collective bargaining with μ set such that the tariff wage is equal to the average wage in the individual bargaining case delivers higher total value added than the baseline individual bargaining economy. There are two main reasons for this. The first one is the existence of young firm wage premium in the baseline economy and the fact that firms discount future profits. Firms face high wage costs when they are far from their target size and this reduces their profitability in the first periods of their life. The young firm wage premium makes it more costly to grow a firm to its target size. This seems to have a large effect on the sum of future expected discounted profits, i.e. the value of firms. This is because a firm takes into account an exogenous death rate δ as well as the standard discount rate r . Removing the young firm pay premium has a large positive effect on expected profits from entry which gives rise to more entry and to a larger stock firms in the steady state (*Firm entry effect*). This leads to higher employment and output.

The second reason why sector-level bargaining delivers higher total value added at the same average wage level seems to be the *Firm size effect*. Under individual wage bargaining firms can lower the wage that they face by hiring more workers and thus reducing their marginal product of labour. This encourages them to grow to a larger size than they would if the wage rate was independent of firm size. While the decision about when to stop growing is privately efficient for the firm (the firm is maximising its value) it may be very inefficient from the point of view of a social planner that is maximising total value added in the economy. This is because a higher average firm size in the economy leads to more resources being spent

on (convex) recruitment costs which are assumed to be a deadweight loss. Furthermore, a higher average firm size leads to a lower average output per worker due to decreasing returns to scale. Therefore a social planner maximising the amount of output that can be consumed would generally choose an allocation with smaller firm sizes than is the case in the model economy with individual wage bargaining.

3.3.4 Experiment 2: Reducing Individual Worker Bargaining Power While Increasing Worker Outside Option

We have seen in the previous section that in the model economy calibrated to the USA reducing wage dispersion (in that case down to 0) while keeping the average wage the same results in a higher total value added. In this section I investigate whether this kind of mean-preserving wage compression can be achieved by adjusting some parameters within the context of a model with individual wage bargaining. Specifically, I simultaneously reduce β , worker bargaining power in individual negotiations, and increase b , the value of leisure, thus raising the worker outside option²⁵. I restrict my attention to such combinations of the two parameters where the average wage is the same as in the original model economy calibrated to the USA. The outcomes for different combinations of β and b are displayed in Table 3.13.

We can see that as we reduce β and increase b , standard deviation of log wages is gradually falling. It starts at 0.041 in Column 1 and ends at just 0.003 in Column 4. As we make these parameter changes, unemployment rate is monotonically decreasing, from 7.06% to 4.94%. Furthermore, this mean-preserving wage compression results in higher total value added which rises from 171.66 to 192.49. The wage compression also results in lower firm productivity cutoff z^* , higher firm entry, larger stock of firms that are on average smaller and in higher output per worker. The smaller is the standard deviation of log wages, the larger is the total production. Total entry, fixed and recruitment costs are also rising as

²⁵ b can also be thought of as unemployment benefit. In this case more generous welfare in the unemployed state would increase the outside option of the workers. The increase in worker outside option is important, because without it a reduction in β would lower the average wage level in the economy.

wage dispersion is reduced. However, total production is rising faster and thus the mean-preserving wage compression results in larger total value added. In conclusion, I demonstrate that we can replicate the aggregate effects of switching to centralised wage bargaining (where the average wage remains the same) in the context of a model economy with individual wage bargaining by reducing worker bargaining power (share of surplus) and increasing worker outside option.

Wage-setting	Individual	Individual	Individual	Individual
Parameters	b=0.85 β =0.481	b=1.1 β =0.16	b=1.45 β =0.06	b=1.57 β =0.02
Average wage	1.647	1.645	1.654	1.642
Standard deviation of log wages	0.041	0.020	0.008	0.003
Total value added	171.66	186.51	192.25	192.49
Unemployment rate	7.06%	5.16%	5.06%	4.94%
Market tightness	0.679	2.240	2.410	2.632
Firm productivity cutoff z^*	1.933	1.861	1.878	1.872
Firm entry	0.078	0.132	0.152	0.157
Successful entry	0.022	0.040	0.045	0.047
Measure of firms	4.042	7.350	8.282	8.637
Output per worker	2.206	2.634	2.771	2.804
Average size of firms	22.994	12.904	11.464	11.006
Total production	205.03	249.85	263.07	266.54
Total wage bill	153.10	155.98	157.04	156.10
Total firm profits	43.26	72.28	83.09	86.03
Total cost of entry	24.70	41.75	47.87	49.64
Total search cost	7.13	18.79	19.79	21.13
Total fixed costs	1.54	2.80	3.15	3.29
Total value of firms	4 927	8 555	9 753	10 130

Table 3.13: The Effects of Increasing Worker Outside Option and Reducing Worker Bargaining Power in Individual Negotiations

3.3.5 Experiment 3: Changing the Degree of Centralisation of Collective Wage Bargaining in Sweden

In this counterfactual experiment I take the model economy with two-tier collective wage bargaining that is calibrated to Sweden and I investigate the effects of changing the effective worker bargaining power at firm-level, $(1 - \epsilon)\omega$. I check and confirm that in all model economies presented in this section the condition (3.46) holds and thus workers are better off staying with the firm during a local disagreement over wage premiums than becoming unemployed, $\tilde{W}_L(n, z) > U$.

Table 3.14 shows outcomes when collective bargaining is gradually centralised i.e. $(1 - \epsilon)\omega$ is decreased. We can see that as wage bargaining is centralised, total value added first rises and then falls. This is mainly because total production first increases and then falls. Standard deviation of log wages is falling massively as firm wage premiums become less dispersed (wages vary less across firms) due to the lower bargaining power of workers at firm-level.

Interestingly, despite the smaller wage premiums, the average wage in the economy actually grows modestly as $(1 - \epsilon)\omega$ declines. The first reason for this is that the tariff wage rises. Negotiators at the sector level can correctly predict the size of the wage premiums that will be agreed at firm-level and they take this into account when setting the tariff wage. We can think of the sector-level negotiations as determining the share of output that will go to workers and the bargaining power of workers at the firm level then determines how much of this will be paid out in wage premiums as opposed to the tariff wage. The second reason is that the size of the joint surplus that firms and workers are splitting at the sector level increases, as the falling $(1 - \epsilon)\omega$ causes a change in the aggregate endogenous objects. The threshold firm productivity level z^* rises and hence only more productive firms (that pay higher wages) can survive in the industry.

Thus the overall *Firm selection effect* here is to increase the selection pressures. There is also the *Firm entry effect*, firm entry rises as $(1 - \epsilon)\omega$ falls. This is because young firm

wage premium is reduced which increases firm profitability in the early periods of a firm's life which due to discounting tends to affect strongly the overall value of the firm. The higher expected profits from entry then encourage more entry. As collective bargaining becomes more centralised, there are more firms that are on average smaller. This is the *Firm size effect*, wage is less tied to the firm's output per worker and thus there is a smaller incentive for firms to grow to a larger size in order to lower the wage rate that they face. Because of stricter selection of firms and the fact that firms are on average smaller (and there are decreasing returns to scale) average labour productivity (output per worker) is higher. On the other hand, unemployment rate is increasing quite sharply in the degree of centralisation. The fact that labour productivity is increasing, but employment is decreasing in the degree of centralisation gives rise to total production and total value added first rising and then falling as firm-level worker bargaining power is restricted. This implies some positive level of $(1 - \epsilon)\omega$ where total value added is maximised, holding all other parameters constant.

Table 3.15 shows the aggregate outcomes as collective bargaining is gradually decentralised i.e. firm-level worker bargaining power $(1 - \epsilon)\omega$ is increased. The patterns are exactly the same as in the analysis above just with opposite sign.

We have seen in the analysis above that when firm-level worker bargaining power is reduced, wage dispersion falls, but the average wage actually increases. This is different from Experiments 1 and 2 where I was exploring the implications of wage compression where the mean wage remains the same. Table 3.16 shows the aggregate implications of such a mean-preserving wage compression in the context of the calibrated economy with two-tier collective bargaining. In order to keep the average wage the same, I am reducing μ , the sector-level union's bargaining power, as I reduce $(1 - \epsilon)\omega$, the firm-level worker bargaining power. Each column displays aggregate outcomes for a different combination of μ and $(1 - \epsilon)\omega$ where the average wage is the same.

We can see that as standard deviation of log wages falls and average wage remains the same, total value added is monotonically rising. Hence I find the same pattern as in the

Wage-setting	Two-tier collective	Two-tier collective	Two-tier collective	Two-tier collective
Parameters	$(1 - \epsilon)\omega = 0.115$	$(1 - \epsilon)\omega = 0.100$	$(1 - \epsilon)\omega = 0.090$	$(1 - \epsilon)\omega = 0.080$
Tariff wage	2.492	2.586	2.659	2.732
Average wage	3.006	3.041	3.074	3.105
Standard deviation of log wages	0.013	0.009	0.006	0.003
Total value added	367.94	370.27	371.32	366.47
Unemployment rate	7.35%	8.00%	9.04%	11.31%
Market tightness	0.206	0.148	0.092	0.037
Firm productivity cutoff z^*	5.170	5.202	5.228	5.263
Firm entry	0.265	0.275	0.281	0.283
Successful entry	0.0087	0.0089	0.0090	0.0089
Measure of firms	5.392	5.525	5.586	5.550
Output per worker	4.482	4.543	4.605	4.662
Average size of firms	17.183	16.649	16.282	15.977
Total production	415.22	417.98	418.93	413.46
Total wage bill	278.49	279.81	279.60	275.40
Total firm profits	121.77	124.01	126.00	125.60
Total cost of entry	32.32	33.55	34.28	34.53
Total search cost	3.27	2.18	1.22	0.42
Total fixed costs	11.68	11.97	12.10	12.02
Total value of firms	21 560	22 036	22 180	21 995

Table 3.14: The Effects of Decreasing Effective Worker Bargaining Power at Firm Level

previous two experiments. There is the *Firm entry effect* as the reduced young firm wage premium encourages more firm entry. The net *Firm selection effect* is to slightly reduce the threshold firm productivity level, thus relaxing selection pressures. Finally, there is also the *Firm size effect*. There are more firms which are on average smaller because wages vary less with firms' output per worker thus reducing the incentive to over-hire.

Wage-setting	Two-tier collective	Two-tier collective	Two-tier collective	Two-tier collective
Parameters	$(1 - \epsilon)\omega = 0.115$	$(1 - \epsilon)\omega = 0.13$	$(1 - \epsilon)\omega = 0.14$	$(1 - \epsilon)\omega = 0.15$
Tariff wage	2.492	2.395	2.335	2.273
Average wage	3.006	2.969	2.947	2.922
Standard deviation of log wages	0.013	0.017	0.019	0.022
Total value added	367.94	363.91	361.09	357.91
Unemployment rate	7.35%	6.90%	6.69%	6.49%
Market tightness	0.206	0.263	0.295	0.331
Firm productivity cutoff z^*	5.170	5.130	5.107	5.078
Firm entry	0.265	0.255	0.249	0.243
Successful entry	0.0087	0.0085	0.0083	0.0082
Measure of firms	5.392	5.281	5.208	5.138
Output per worker	4.482	4.414	4.372	4.327
Average size of firms	17.183	17.626	17.912	18.195
Total production	415.22	410.95	407.95	404.62
Total wage bill	278.49	276.43	274.98	273.26
Total firm profits	121.77	118.62	116.54	114.31
Total cost of entry	32.32	31.15	30.43	29.66
Total search cost	3.27	4.44	5.14	5.91
Total fixed costs	11.68	11.44	11.28	11.13
Total value of firms	21 560	21 102	20 793	20 466

Table 3.15: The Effects of Increasing Effective Worker Bargaining Power at Firm Level

Wage-setting	Two-tier collective	Two-tier collective	Two-tier collective	Two-tier collective
Parameters	$(1 - \epsilon)\omega = 0.115$	$(1 - \epsilon)\omega = 0.100$	$(1 - \epsilon)\omega = 0.090$	$(1 - \epsilon)\omega = 0.080$
	$\mu = 0.546$	$\mu = 0.539$	$\mu = 0.535$	$\mu = 0.530$
Tariff wage	2.492	2.552	2.598	2.636
Average wage	3.006	3.004	3.008	3.001
Standard deviation of log wages	0.013	0.011	0.010	0.009
Total value added	367.94	370.79	372.74	374.49
Unemployment rate	7.35%	7.20%	7.19%	7.01%
Market tightness	0.206	0.222	0.224	0.247
Firm productivity cutoff z^*	5.170	5.165	5.167	5.157
Firm entry	0.265	0.271	0.276	0.281
Successful entry	0.0087	0.0089	0.009	0.009
Measure of firms	5.392	5.544	5.639	5.754
Output per worker	4.482	4.520	4.549	4.572
Average size of firms	17.183	16.730	16.456	16.157
Total production	415.22	419.50	422.24	425.19
Total wage bill	278.49	278.83	279.19	279.12
Total firm profits	121.77	125.13	127.31	129.68
Total cost of entry	32.32	33.16	33.76	34.32
Total search cost	3.27	3.52	3.51	3.91
Total fixed costs	11.68	12.01	12.21	12.46
Total value of firms	21 560	22 170	22 548	23 000

Table 3.16: The Effects of Decreasing Effective Worker Bargaining Power at Firm Level While Keeping Average Wage Constant

3.4 Conclusion

In this chapter I compare individual wage bargaining with two-tier collective bargaining where first a common tariff wage is set at sector-level and then additional wage premiums are bargained collectively at firm-level. The model can vary the extent of centralisation of wage bargaining by adjusting the ability of workers to reduce their level of effort during firm-level disagreement over pay. Under both wage setting regimes there is a wage dispersion among homogeneous workers driven by rent sharing and the wage is an increasing function of the firm's output per worker. Because of convex hiring costs firms only gradually grow towards their target size. Given that firm productivity is constant over the life of the firm and there are decreasing returns to scale, wage is declining in firm age. Firms with higher permanent productivity face higher wages along their entire growth path.

My first contribution is to provide a novel explanation for the recent empirical finding of a young firm wage premium. Babina et al. (2019) and Schmieder (2013) find that after controlling for employer and worker time-invariant heterogeneity using fixed effects there is a statistically and economically significant young-firm pay premium that is monotonically decreasing with firm age. In my model when firms are young they have few workers relative to their target size and thus their marginal product of labour is relatively high. In individual negotiations a worker can threaten to leave and it takes time and resources to replace her. When a firm is young each worker is more valuable to the company than when the same firm is older and it had time to grow to its target size. Hence workers are able to negotiate a higher wage when the firm is young.

My second contribution is to identify the aggregate implications of equalising wages for homogeneous workers across heterogeneous firms. My main finding is that reducing wage dispersion while holding the average wage the same leads to a higher total value added. There are two main reasons for this. The first one is the existence of the young firm wage premium and the fact that firms discount future profits. Under firm-level wage bargaining (either individual or collective) firms face high wage costs when they are far from their target

size and this reduces their profitability in the first periods of their life. Reducing the young firm wage premium increases firm profitability in the early periods which due to discounting has a large positive effect on the value of firms. Higher expected profits from entry lead to more entry and to a higher stock of firms. This leads to higher employment and output.

The second reason is that when wages are increasing in the firm's marginal (or average) product of labour firms can lower the wage that they face by hiring more workers (E. Smith (1999), Cahuc and Wasmer (2001)). This encourages them to grow to a larger size than they would if the wage rate was independent of firm size. While the decision about when to stop growing is privately efficient for the firm (the firm is maximising its value) it may be very inefficient from the point of view of a social planner that is maximising the total value added in the economy. This is because a higher average firm size in the economy leads to more resources being spent on (convex) recruitment costs which are assumed to be a deadweight loss. Furthermore, a higher average firm size leads to a lower average output per worker due to decreasing returns to scale. Therefore a social planner maximising the amount of output that can be consumed would generally choose an allocation with smaller firm sizes than is the case in the model economy with firm-level wage bargaining (either individual or collective).

In all of my simulations mean-preserving wage compression leads to a higher total production of the final good, as there are more employed workers and labour productivity is higher. While the sum of the three types of costs that are assumed to be a deadweight loss (entry, fixed and recruitment) also rises, the increase in total production is larger and thus total value added is increased.

In conclusion, this chapter argues that the wage dispersion driven by firm characteristics via rent sharing has negative efficiency implications, as it discourages firm entry and encourages over-employment by firms. Furthermore, I show that centralisation of wage bargaining, i.e. moving wage bargaining to the level of the sector and reducing the effective bargaining power of workers at the firm level, can reduce this kind of wage dispersion and thus result

in better aggregate outcomes.

3.5 Appendix

3.5.1 Proofs

Proof of Proposition 1: First, substitute the expression for the value of an employed worker (3.6) into the surplus-splitting equation (3.14).

$$w^I(n, z) + \frac{s + \delta - s\delta}{1 + r}U + \frac{1 - s - \delta + s\delta}{1 + r}W(n', z) - U = \frac{\beta}{1 - \beta} \frac{\partial \Pi(n, z)}{\partial n} \quad (3.63)$$

The surplus-splitting rule gives

$$W(n, z) = \frac{\beta}{1 - \beta} \frac{\partial \Pi(n, z)}{\partial n} + U \quad (3.64)$$

and thus also

$$W(n', z) = \frac{\beta}{1 - \beta} \frac{\partial \Pi(n', z)}{\partial n'} + U \quad (3.65)$$

Substitute for $W(n', z)$ in (3.63) and simplify to obtain:

$$w^I(n, z) = \frac{rU}{1 + r} + \frac{\beta}{1 - \beta} \left[\frac{\partial \Pi(n, z)}{\partial n} - \frac{1 - s - \delta + s\delta}{1 + r} \frac{\partial \Pi(n', z)}{\partial n'} \right] \quad (3.66)$$

Differentiating the maximised firm value equation (3.3) with respect to current employment n , using the envelope condition and the law of motion of employment:

$$\frac{\partial \Pi(n, z)}{\partial n} = \frac{\partial y(n, z)}{\partial n} - w^I(n, z) - \frac{\partial w^I(n, z)}{\partial n}n + \frac{1 - \delta}{1 + r} \frac{\partial \Pi(n', z)}{\partial n'}(1 - s) \quad (3.67)$$

Substitute for $\frac{\partial \Pi(n', z)}{\partial n'}$ in the above from the first-order condition for vacancies (3.4).

$$\frac{\partial \Pi(n, z)}{\partial n} = \frac{\partial y(n, z)}{\partial n} - w^I(n, z) - \frac{\partial w^I(n, z)}{\partial n}n + (1 - s) \frac{c'(v)}{q(\theta)} \quad (3.68)$$

Next, in (3.66) substitute for $\frac{\partial \Pi(n, z)}{\partial n}$ from (3.68) and for $\frac{\partial \Pi(n', z)}{\partial n'}$ from (3.4). After simplifying this gives

$$w^I(n, z) = (1 - \beta) \frac{rU}{1 + r} + \beta \frac{\partial y(n, z)}{\partial n} - \beta \frac{\partial w(n, z)}{\partial n}n \quad (3.69)$$

Proof of Lemma 1: From Proposition 1 wage under individual bargaining is the solution

to the following differential equation:

$$w^I(n, z) = (1 - \beta) \frac{rU}{1 + r} + \beta \frac{\partial y(n, z)}{\partial n} - \beta \frac{\partial w(n, z)}{\partial n} n \quad (3.70)$$

If we think of z as a constant then the above is a linear ordinary differential equation of first order and thus it is possible to solve it analytically. Using the fact that the production function is Cobb-Douglas and following the usual procedure for solving differential equations of the form $\frac{dy}{dx} + p(x)y = Q(x)$ we obtain:

$$w^I(n, z) = \frac{(1 - \beta)rU}{1 + r} + \frac{\alpha\beta}{\alpha\beta + 1 - \beta} z n^{\alpha-1} + \frac{c}{n^{1/\beta}} \quad (3.71)$$

Notice that if $c > 0$ then as $n \rightarrow 0$, $\frac{c}{n^{1/\beta}} \rightarrow +\infty$ which means that $w(n) \rightarrow +\infty$. Following Acemoglu and Hawkins (2014) I assume that as $n \rightarrow 0$ the wage does not grow to infinity, it is still finite and hence I set $c=0$. Then I obtain:

$$w^I(n, z) = (1 - \beta) \frac{rU}{1 + r} + \frac{\alpha\beta}{(\alpha\beta + 1 - \beta)} \frac{z}{n^{1-\alpha}} \quad (3.72)$$

We can confirm that this is indeed the solution to the differential equation by using (3.72) as $w(n, z)$ in (3.70) and solving.

Proof of Lemma 2: The value of an unemployed worker is given by:

$$U = b + \frac{1}{1 + r} \left\{ \theta q(\theta) \int_{z^*}^{\infty} \int_0^{n^*(z)} W(n, z) \frac{v(n, z)h(n, z)}{v_{tot}} dn dz + (1 - \theta q(\theta))U \right\} \quad (3.73)$$

We substitute for the value of an employed worker $W(n, z)$ from the surplus-splitting equation (3.64).

$$U = b + \frac{1}{1 + r} \left\{ \theta q(\theta) \int_{z^*}^{\infty} \int_0^{n^*(z)} \left(\frac{\beta}{1 - \beta} \frac{\partial \Pi(n, z)}{\partial n} + U \right) \frac{v(n, z)h(n, z)}{v_{tot}} dn dz + (1 - \theta q(\theta))U \right\} \quad (3.74)$$

$\frac{\beta}{1-\beta}$ is a constant and thus can be taken out of the integral. U is also not a function of n or

z.

$$U = b + \frac{1}{1+r} \left\{ \theta q(\theta) \frac{\beta}{1-\beta} \int_{z^*}^{\infty} \int_0^{n^*(z)} \frac{\partial \Pi(n, z)}{\partial n} \frac{v(n, z) h(n, z)}{v_{tot}} dn dz \right. \\ \left. + \theta q(\theta) U + (1 - \theta q(\theta)) U \right\} \quad (3.75)$$

Simplifying and moving all U terms to the left hand side.

$$\frac{r}{1+r} U = b + \frac{1}{1+r} \left\{ \theta q(\theta) \frac{\beta}{1-\beta} \int_{z^*}^{\infty} \int_0^{n^*(z)} \frac{\partial \Pi(n, z)}{\partial n} \frac{v(n, z) h(n, z)}{v_{tot}} dn dz \right\} \quad (3.76)$$

Finally, we obtain:

$$rU = (1+r)b + \theta q(\theta) \frac{\beta}{1-\beta} \int_{z^*}^{\infty} \int_0^{n^*(z)} \frac{\partial \Pi(n, z)}{\partial n} \frac{v(n, z) h(n, z)}{v_{tot}} dn dz \quad (3.77)$$

Proof of Lemma 3: Value of the firm at the target size is given by the following.

$$\Pi(n^*, z) = y(n^*, z) - n^* w^I(n^*, z) - F^p - c(v(n^*, z)) + \frac{1-\delta}{1+r} \Pi(n^*, z) \quad (3.78)$$

This can be rearranged to obtain the following.

$$\Pi(n^*, z) = \frac{1+r}{r+\delta} \left[y(n^*, z) - n^* w^I(n^*, z) - F^p - c(v(n^*, z)) \right] \quad (3.79)$$

Taking a derivative with respect to n^* and applying the Envelope condition, i.e. $\frac{\partial v(n^*, z)}{\partial n^*} = 0$.

$$\frac{\partial \Pi(n^*, z)}{\partial n^*} = \frac{1+r}{r+\delta} \left[\frac{\partial y(n^*, z)}{\partial n^*} - w^I(n^*, z) - n^* \frac{\partial w^I(n^*, z)}{\partial n^*} \right] \quad (3.80)$$

First-order condition (3.4) for the firm at the target size is given by:

$$\frac{c'(v(n^*, z))}{q(\theta)} = \frac{1-\delta}{1+r} \frac{\partial \Pi(n^*, z)}{\partial n^*} \quad (3.81)$$

Substituting (3.80) into (3.81) we obtain the following.

$$\frac{c'(v(n^*, z))}{q(\theta)} = \frac{1-\delta}{r+\delta} \left[\frac{\partial y(n^*, z)}{\partial n^*} - w^I(n^*, z) - n^* \frac{\partial w^I(n^*, z)}{\partial n^*} \right] \quad (3.82)$$

Next we have to substitute for $c'(v(n^*, z))$, $\frac{\partial y(n^*, z)}{\partial n^*}$, $w^I(n^*, z)$ and $\frac{\partial w^I(n^*, z)}{\partial n^*}$. We know that the marginal vacancy cost takes the form:

$$c'(v(n, z)) = \lambda + \gamma v(n, z) \quad (3.83)$$

The law of motion of firm size is given by:

$$n' = (1 - s)n + v(n, z)q(\theta) \quad (3.84)$$

Target firm size n^* is defined as $n = n' = n^*$.

$$n^* = (1 - s)n^* + v(n^*, z)q(\theta) \quad (3.85)$$

Rearranging the above for $v(n^*, z)$

$$v(n^*, z) = \frac{sn^*}{q(\theta)} \quad (3.86)$$

Combining (3.83) and (3.86)

$$c'(v(n^*, z)) = \lambda + \gamma \frac{sn^*}{q(\theta)} \quad (3.87)$$

Given that the production function is Cobb-Douglas, $y(n^*, z) = z(n^*)^\alpha$, marginal product of labour is given by

$$\frac{\partial y(n^*, z)}{\partial n^*} = \alpha z(n^*)^{\alpha-1} \quad (3.88)$$

Wage under individual bargaining is given by Lemma 1. Its derivative with respect to firm size is given by

$$\frac{\partial w^I(n^*, z)}{\partial n^*} = (\alpha - 1) \frac{\alpha\beta}{\alpha\beta + 1 - \beta} z(n^*)^{\alpha-2} \quad (3.89)$$

After substitution (3.82) becomes

$$\frac{\lambda + \gamma \frac{sn^*}{q(\theta)}}{q(\theta)} = \frac{1 - \delta}{r + \delta} \left[\alpha z(n^*)^{\alpha-1} - (1 - \beta) \frac{rU}{1 + r} - \frac{\alpha\beta}{(\alpha\beta + 1 - \beta)} z(n^*)^{\alpha-1} - n^*(\alpha - 1) \frac{\alpha\beta}{\alpha\beta + 1 - \beta} z(n^*)^{\alpha-2} \right] \quad (3.90)$$

Simplifying the above we obtain the final expression.

$$\frac{\lambda}{q(\theta)} + \frac{1 - \delta}{r + \delta} \frac{1 - \beta}{1 + r} rU + \frac{\gamma s}{q^2(\theta)} n^* - \frac{1 - \delta}{r + \delta} \frac{\alpha(1 - \beta)}{\alpha\beta + 1 - \beta} z n^{*(\alpha-1)} = 0 \quad (3.91)$$

This is an implicit function for the target size $n^*(z)$. I prove that $n^*(z)$ is increasing in z by

showing that the left-hand-side of this expression is decreasing in z , while it is increasing in n^* .

$$\frac{\partial LHS}{\partial z} = -\frac{1-\delta}{r+\delta} \frac{\alpha(1-\beta)}{\alpha\beta+1-\beta} (n^*)^{\alpha-1} < 0 \quad (3.92)$$

Given that $\delta \in (0, 1)$, $r > 0$, $\alpha \in (0, 1)$ and $\beta \in (0, 1)$ the derivative above is negative. The left-hand side of (3.91) is decreasing in z .

$$\frac{\partial LHS}{\partial n^*} = \frac{\gamma s}{q(\theta)^2} + \frac{(1-\alpha)(1-\delta)}{r+\delta} \frac{\alpha(1-\beta)}{\alpha\beta+1-\beta} z(n^*)^{\alpha-1} > 0 \quad (3.93)$$

Given that $\gamma > 0$, $s > 0$, $r > 0$, $\delta \in (0, 1)$, $\alpha \in (0, 1)$ and $\beta \in (0, 1)$, the derivative above is positive. Hence the left-hand side of (3.91) is increasing in n^* .

Therefore there is a positive relationship between z and n^* . More productive firms grow towards a larger target size.

Proof of Lemma 4: Per-period profit of a firm is given by:

$$\pi(n, z) = y(n, z) - w^I(n, z)n - F^p - c(v(n, z)) \quad (3.94)$$

Differentiating it we obtain

$$\begin{aligned} \frac{\partial \pi(n, z)}{\partial n} &= \frac{\partial y(n, z)}{\partial n} - w^I(n, z) - n \frac{\partial w^I(n, z)}{\partial n} - c'(v(n, z)) \frac{\partial v(n, z)}{\partial n} \\ &= \frac{\partial y(n, z)}{\partial n} - w^I(n, z) - n \frac{\partial w^I(n, z)}{\partial n} \end{aligned} \quad (3.95)$$

because $\frac{\partial v(n, z)}{\partial n} = 0$. Using $y(n, z) = zn^\alpha$ and $w^I(n, z) = (1-\beta) \frac{rU}{1+r} + \frac{\alpha\beta}{(\alpha\beta+1-\beta)} \frac{z}{n^{1-\alpha}}$ we obtain the following:

$$\frac{\partial \pi(n, z)}{\partial n} = \alpha zn^{\alpha-1} - (1-\beta) \frac{rU}{1+r} - \frac{\alpha\beta}{\alpha\beta+1-\beta} zn^{\alpha-1} - n \frac{(\alpha-1)\alpha\beta}{\alpha\beta+1-\beta} zn^{\alpha-2} \quad (3.96)$$

Simplifying the expression above and multiplying both sides by β :

$$\beta \frac{\partial \pi(n, z)}{\partial n} = -\beta \frac{1-\beta}{1+r} rU + (1-\beta) \left(\frac{\alpha\beta}{\alpha\beta+1-\beta} zn^{\alpha-1} \right) \quad (3.97)$$

Taking the expression for wage under individual bargaining from Lemma (1) and rearranging it:

$$\frac{\alpha\beta}{(\alpha\beta+1-\beta)} zn^{\alpha-1} = w^I(n, z) - (1-\beta) \frac{rU}{1+r} \quad (3.98)$$

Substituting (3.98) into (3.97):

$$\beta \frac{\partial \pi(n, z)}{\partial n} = -\beta \frac{1-\beta}{1+r} rU + (1-\beta) \left(w^I(n, z) - (1-\beta) \frac{rU}{1+r} \right) \quad (3.99)$$

Simplifying and rearranging this for $w(n, z)$:

$$w^I(n, z) = \frac{rU}{1+r} + \frac{\beta}{1-\beta} \frac{\partial \pi(n, z)}{\partial n} \quad (3.100)$$

Thus wage is increasing in the worker outside option and in the firm's surplus from employing the marginal worker.

Value of a firm that is at its target size:

$$\Pi(n^*(z), z) = y(n^*(z), z) - n^*(z)w^I(n^*(z), z) - F^p - c(v(n^*(z), z)) + \frac{1-\delta}{1+r} \Pi(n^*(z), z) \quad (3.101)$$

Simplifying the above:

$$\Pi(n^*(z), z) = \frac{1+r}{r+\delta} \pi(n^*(z), z) \quad (3.102)$$

The first-order condition for vacancy-posting for a firm at its target size is given by:

$$\frac{c'(v(n^*(z), z))}{q(\theta)} = \frac{1-\delta}{1+r} \frac{\partial \Pi(n^*(z), z)}{\partial n} \quad (3.103)$$

Differentiating (3.102) with respect to n :

$$\frac{\partial \Pi(n^*(z), z)}{\partial n} = \frac{1+r}{r+\delta} \frac{\partial \pi(n^*(z), z)}{\partial n} \quad (3.104)$$

Substituting (3.104) into (3.103) and rearranging:

$$\frac{\partial \pi(n^*(z), z)}{\partial n} = \frac{r+\delta}{1-\delta} \frac{c'(v(n^*(z), z))}{q(\theta)} \quad (3.105)$$

Finally, substituting (3.105) into (3.100) evaluated at $n = n^*(z)$ and using the fact that at $n^*(z)$ every period the number of workers hired is equal to the number of workers that the firm is losing due to exogenous match separations and thus $v(n^*(z), z)q(\theta) = sn^*(z)$ we obtain:

$$w^I(n^*(z), z) = \frac{rU}{1+r} + \frac{\beta}{1-\beta} \frac{r+\delta}{1-\delta} \frac{c'\left(\frac{sn^*(z)}{q(\theta)}\right)}{q(\theta)} \quad (3.106)$$

Proof of Lemma 5: The chosen wage premium maximizes the weighted product of the firm's and the firm-level union's surplus:

$$\max_{p \geq 0} \left(np \right)^\omega \left((1 - \epsilon)y(n, z) - np \right)^{1-\omega} \quad (3.107)$$

where $\omega \in (0, 1)$ represents bargaining power of workers at the firm-level.

The first-order condition of the above maximisation problem is given by:

$$\omega \left(np \right)^{\omega-1} n \left((1 - \epsilon)y(n, z) - np \right)^{1-\omega} - (1 - \omega) \left((1 - \epsilon)y(n, z) - np \right)^{-\omega} n \left(np \right)^\omega = 0 \quad (3.108)$$

Simplifying the above:

$$w((1 - \epsilon)y(n, z) - np) - (1 - \omega)np = 0 \quad (3.109)$$

Solving the above for p we obtain the expression for wage premium:

$$p(n, z) = (1 - \epsilon)\omega \frac{y(n, z)}{n} \quad (3.110)$$

Assuming Cobb-Douglas production function $y(n, z) = zn^\alpha$:

$$p(n, z) = (1 - \epsilon)\omega \frac{z}{n^{1-\alpha}} \quad (3.111)$$

The tariff wage maximizes the weighted product of the sector-wide union's and the employer organisation's surplus:

$$\max_{T \geq 0} \left(TL + (1 - \epsilon)\omega Y - bL \right)^\mu \left((1 - (1 - \epsilon)\omega)Y - TL \right)^{1-\mu} \quad (3.112)$$

where $\mu \in (0, 1)$ represents bargaining power of the sector-level union. I assume that the sector-wide union and the employer organisation take the aggregate output Y and aggregate employment L as given. Thus they do not internalize the effect that the choice of the tariff wage has on these variables.

The first-order condition of the above maximisation problem is given by:

$$\begin{aligned} & \mu \left(TL + (1 - \epsilon)\omega Y - bL \right)^{\mu-1} L \left((1 - (1 - \epsilon)\omega)Y - TL \right)^{1-\mu} \\ & - (1 - \mu) \left(TL + (1 - \epsilon)\omega Y - bL \right)^\mu \left((1 - (1 - \epsilon)\omega)Y - TL \right)^{-\mu} L = 0 \end{aligned} \quad (3.113)$$

Simplifying the above:

$$\mu \left((1 - (1 - \epsilon)\omega)Y - TL \right) - (1 - \mu) \left(TL + (1 - \epsilon)\omega Y - bL \right) = 0 \quad (3.114)$$

Solving the above for T we obtain the expression for tariff wage:

$$T = (1 - \mu)b + \left(\mu - (1 - \epsilon)\omega \right) \frac{Y}{L} \quad (3.115)$$

Putting the above two results together:

$$\begin{aligned} w^C(n, z) &= T + p(n, z) \\ &= (1 - \mu)b + \left(\mu - (1 - \epsilon)\omega \right) \frac{Y}{L} + (1 - \epsilon)\omega \frac{z}{n^{1-\alpha}} \end{aligned} \quad (3.116)$$

Proof of Lemma 6: We can use (3.82) from the proof of Lemma 3 because all the steps up to that point are independent of the wage setting regime.

$$\frac{c'(v(n^*, z))}{q(\theta)} = \frac{1 - \delta}{r + \delta} \left[\frac{\partial y(n^*, z)}{\partial n} - w^C(n^*, z) - n^* \frac{\partial w^C(n^*, z)}{\partial n} \right] \quad (3.117)$$

The wage under two-tier collective bargaining is given by (5). Evaluated at firm target size:

$$w^C(n^*, z) = T + (1 - \epsilon)\omega z(n^*)^{\alpha-1} \quad (3.118)$$

Its derivative with respect to firm size is given by:

$$\frac{\partial w^C(n^*, z)}{\partial n} = -(1 - \alpha)(1 - \epsilon)\omega z(n^*)^{\alpha-2} < 0 \quad (3.119)$$

Next in (3.117) we substitute for $c'(v(n^*, z))$ from (3.87), for $\frac{\partial y(n^*, z)}{\partial n}$ from (3.88), for $w^C(n^*, z)$ from (3.118) and for $\frac{\partial w^C(n^*, z)}{\partial n}$ from (3.119). Thus we obtain:

$$\frac{\lambda}{q(\theta)} + \frac{\gamma s}{q(\theta)^2} n^* = \frac{1 - \delta}{r + \delta} \left[\alpha z(n^*)^{\alpha-1} - T - (1 - \epsilon)\omega z(n^*)^{\alpha-1} + n^*(1 - \alpha)(1 - \epsilon)\omega z(n^*)^{\alpha-2} \right] \quad (3.120)$$

Simplifying the above we obtain an implicit function for firm target size $n^*(z)$ under two-tier collective bargaining.

$$\frac{\lambda}{q(\theta)} + \frac{\gamma s}{q(\theta)^2} n^* + \frac{1 - \delta}{r + \delta} T - \frac{(1 - \delta)(1 - \omega(1 - \epsilon))\alpha}{r + \delta} z(n^*)^{\alpha-1} = 0 \quad (3.121)$$

I prove that $n^*(z)$ is increasing in z by showing that the left-hand-side of this expression is decreasing in z , while it is increasing in n^* .

$$\frac{\partial LHS}{\partial z} = -\frac{(1-\delta)(1-\omega(1-\epsilon))\alpha}{r+\delta}(n^*)^{\alpha-1} < 0 \quad (3.122)$$

Given that $\delta \in (0, 1)$, $\alpha \in (0, 1)$, $\epsilon \in (0, 1)$ and $\omega \in (0, 1)$ the derivative above is negative. The left-hand side of (3.121) is decreasing in z .

$$\frac{\partial LHS}{\partial n^*} = \frac{\gamma s}{q(\theta)^2} + \frac{(1-\alpha)(1-\delta)(1-\omega(1-\epsilon))\alpha}{r+\delta} z(n^*)^{\alpha-2} > 0 \quad (3.123)$$

Given that $\gamma > 0$, $r > 0$, $s \in (0, 1)$, $\delta \in (0, 1)$, $\alpha \in (0, 1)$, $\epsilon \in (0, 1)$ and $\omega \in (0, 1)$, the derivative above is positive. Hence the left-hand side of (3.121) is increasing in n^* .

Therefore there is a positive relationship between z and n^* . More productive firms grow towards a larger target size.

Proof of Lemma 7: Per-period profit of a firm is given by:

$$\pi(n, z) = y(n, z) - w^C(n, z)n - F^p - c(v(n, z)) \quad (3.124)$$

Differentiating it we obtain

$$\begin{aligned} \frac{\partial \pi(n, z)}{\partial n} &= \frac{\partial y(n, z)}{\partial n} - w^C(n, z) - n \frac{\partial w^C(n, z)}{\partial n} - c'(v(n, z)) \frac{\partial v(n, z)}{\partial n} \\ &= \frac{\partial y(n, z)}{\partial n} - w^C(n, z) - n \frac{\partial w^C(n, z)}{\partial n} \end{aligned} \quad (3.125)$$

because $\frac{\partial v(n, z)}{\partial n} = 0$. Using $y(n, z) = zn^\alpha$ and $w^C(n, z) = T + (1-\epsilon)\omega zn^{\alpha-1}$ we obtain the following:

$$\frac{\partial \pi(n, z)}{\partial n} = \alpha zn^{\alpha-1} - T - (1-\epsilon)\omega zn^{\alpha-1} - n \left(-(1-\alpha)(1-\epsilon)\omega zn^{\alpha-2} \right) \quad (3.126)$$

Simplifying the expression above:

$$\frac{\partial \pi(n, z)}{\partial n} = \left(1 - (1-\epsilon)\omega \right) \alpha zn^{\alpha-1} - T \quad (3.127)$$

Rearranging the above for output per worker:

$$zn^{\alpha-1} = \frac{\frac{\partial \pi(n, z)}{\partial n} + T}{\alpha \left(1 - (1-\epsilon)\omega \right)} \quad (3.128)$$

Substituting (3.128) into the expression for wage under two-tier collective bargaining:

$$w^C(n, z) = T + (1 - \epsilon)\omega \frac{\left(\frac{\partial \pi(n, z)}{\partial n} + T\right)}{\alpha(1 - (1 - \epsilon)\omega)} \quad (3.129)$$

Simplifying the above:

$$w^C(n, z) = \frac{\alpha - (1 - \alpha)(1 - \epsilon)\omega}{\alpha - \alpha(1 - \epsilon)\omega} T + \frac{(1 - \epsilon)\omega}{\alpha - \alpha(1 - \epsilon)\omega} \frac{\partial \pi(n, z)}{\partial n} \quad (3.130)$$

Value of a firm that is at its target size:

$$\Pi(n^*(z), z) = y(n^*(z), z) - n^*(z)w^C(n^*(z), z) - F^p - c(v(n^*(z), z)) + \frac{1 - \delta}{1 + r} \Pi(n^*(z), z) \quad (3.131)$$

Simplifying the above:

$$\Pi(n^*(z), z) = \frac{1 + r}{r + \delta} \pi(n^*(z), z) \quad (3.132)$$

The first-order condition for vacancy-posting for a firm at its target size is given by:

$$\frac{c'(v(n^*(z), z))}{q(\theta)} = \frac{1 - \delta}{1 + r} \frac{\partial \Pi(n^*(z), z)}{\partial n} \quad (3.133)$$

Differentiating (3.132) with respect to n:

$$\frac{\partial \Pi(n^*(z), z)}{\partial n} = \frac{1 + r}{r + \delta} \frac{\partial \pi(n^*(z), z)}{\partial n} \quad (3.134)$$

Substituting (3.134) into (3.133) and rearranging:

$$\frac{\partial \pi(n^*(z), z)}{\partial n} = \frac{r + \delta}{1 - \delta} \frac{c'(v(n^*(z), z))}{q(\theta)} \quad (3.135)$$

Finally, substituting (3.135) into (3.130) evaluated at $n = n^*(z)$ and using the fact that at $n^*(z)$ every period the number of workers hired is equal to the number of workers that the firm is losing due to exogenous match separations and thus $v(n^*(z), z)q(\theta) = sn^*(z)$ we obtain:

$$w^C(n^*(z), z) = \frac{\alpha - (1 - \alpha)(1 - \epsilon)\omega}{\alpha - \alpha(1 - \epsilon)\omega} T + \frac{(1 - \epsilon)\omega}{\alpha - \alpha(1 - \epsilon)\omega} \frac{r + \delta}{1 - \delta} \frac{c'\left(\frac{sn^*(z)}{q(\theta)}\right)}{q(\theta)} \quad (3.136)$$

We know from Lemma 6 that the firms with larger time-invariant productivity grow towards a larger target size; $n^*(z)$ is increasing in z . Hence the number of vacancies posted by a firm at its target size, $\frac{sn^*(z)}{q(\theta)}$, is increasing in z . Marginal cost of posting vacancies $c'(v)$ is increasing in the number of vacancies. Therefore $c'\left(\frac{sn^*(z)}{q(\theta)}\right)$ is increasing in z . Finally, $w^C\left(n^*(z), z\right)$ is increasing in z . Firms with larger permanent productivity z pay higher wages at their respective target size.

3.5.2 Wage Bargaining with Firm-level Unions

In this case collective bargaining is completely decentralised in the sense that there are no negotiations at sector-level and instead negotiations take place between a firm-level union and a particular firm. The threat point is the possibility of a strike, for one period there is no production. Both parties take up the negotiation again the next period. During the strike workers continue to be employed, they do not receive any wages, but they get the value of leisure, b . The firm cannot produce for one period, it is not paying out wages, but it still has to pay vacancy cost and the fixed cost. The choice of vacancies is forward-looking and thus it is unaffected by whether there is a strike today or not. Wage is the result of bilateral Nash bargaining.

Value of the firm in the case of an agreement:

$$\begin{aligned}\Pi_{FL}(n, z) = & y(n, z) - nw^{FL}(n, z) - F^p - c(v(n, z)) \\ & + \frac{1-\delta}{1+r} \Pi\left(n - sn + q(\theta)v(n, z), z\right)\end{aligned}\quad (3.137)$$

Value of the firm in the case of a strike:

$$\tilde{\Pi}_{FL}(n, z) = -F^p - c(v(n, z)) + \frac{1-\delta}{1+r} \Pi\left(n - sn + q(\theta)v(n, z), z\right)\quad (3.138)$$

Firm's gain from an agreement: $\Pi_{FL}(n, z) - \tilde{\Pi}_{FL}(n, z) = y(n, z) - nw^{FL}(n, z)$

Value of the worker in the case of an agreement:

$$\begin{aligned}W_{FL}(n, z) = & w^{FL}(n, z) + \frac{1}{1+r} \left\{ (s + \delta - s\delta)U \right. \\ & \left. + (1 - s - \delta + s\delta)W\left(n - sn + q(\theta)v(n, z), z\right) \right\}\end{aligned}\quad (3.139)$$

Value of the worker in the case of a strike:

$$\begin{aligned} \tilde{W}_{FL}(n, z) = b + \frac{1}{1+r} & \left\{ (s + \delta - s\delta)U \right. \\ & \left. + (1 - s - \delta + s\delta)W(n - sn + q(\theta)v(n, z), z) \right\} \end{aligned} \quad (3.140)$$

Surplus of each worker: $W_{FL}(n, z) - \tilde{W}_{FL}(n, z) = w^{FL}(n, z) - b$

Union's gain from an agreement (surplus): $n(w^{FL}(n, z) - b)$

The chosen wage maximizes the weighted product of firm and union surplus:

$$\max_{w^{FL} \geq 0} \left(n (w^{FL} - b) \right)^\omega \left(y(n, z) - nw^{FL} \right)^{1-\omega} \quad (3.141)$$

where ω captures bargaining power of the firm-level union.

Wage under firm-level unions is given by:

$$w^{FL}(n, z) = (1 - \omega) b + \omega \frac{y(n, z)}{n} \quad (3.142)$$

Wage is an increasing function of the value of leisure b and of average product of labour of the firm. Assuming Cobb-Douglas production function $y(n, z) = zn^\alpha$ the wage under firm-level unions becomes:

$$w^{FL}(n, z) = (1 - \omega) b + \omega \frac{z}{n^{1-\alpha}} \quad (3.143)$$

Holding employment constant, wage is increasing in firm productivity. Holding firm productivity constant, wage is decreasing in employment.

3.5.3 Solving the model numerically

3.5.3.1 Model with individual wage bargaining

The critical endogenous variables are: the labour market tightness θ , the flow value of unemployment rU and the level of firm entry e . All other endogenous objects of the model are just a function of these three variables and constant parameters. First, I solve a system of 2 non-linear equations and 2 unknowns: θ and rU . Once I know the equilibrium values of θ and rU , I solve for e . Finally, I can solve for all the endogenous objects of the model, generate model moments and compare them with data moments and calibrate parameters.

The following is a system of 2 equations that are functions of θ and rU only (not of e)²⁶.

$$rU_{guess} - rU_{new} = 0$$

$$rU_{guess} - \left[(1+r)b + \frac{\theta q(\theta)\beta}{1-\beta} \int_{z^*}^{\infty} \int_0^{n^*(z)} \frac{\partial \Pi(n, z)}{\partial n} \frac{v(n, z)h(n, z)}{v_{tot}} dndz \right] = 0 \quad (3.144)$$

$$\int_{z^*}^{\infty} \Pi(0, z) f(z) dz - F^e = 0 \quad (3.145)$$

I solve the above system of two non-linear equations using the following algorithm:

Algorithm 1 *Solving for θ and rU :*

1. *Guess θ and rU .*
2. *Apply value function iteration on (3.3) to solve for the value function $\Pi(n, z)$, the policy function $n'(n)$ and $v(n, z)$.*
3. *Calculate the firm target size $n^*(z)$ which is given by Lemma 3.*
4. *Solve for z^* using the Minimum Productivity Condition (3.12).*
5. *Given $v(n, z)$, θ , $n^*(z)$ and z^* , find the joint distribution of firm size and productivity $h(n, z)$ - steps in Appendix 3.5.3.4.*
6. *Check how close equations (3.144-3.145) are to zero. If sufficiently close, stop. We found θ^* and rU^* . If not, go to Step 1 and update the guess of θ, rU .*

Once I have found the equilibrium θ^* and rU^* I solve for the level of entry, e . Given that I know θ^* , I can solve for the equilibrium unemployment rate from the Beveridge curve.

$$u^* = \frac{tsr}{tsr + jfr} = \frac{\delta + (1 - \delta)s}{\delta + (1 - \delta)s + \theta^* q(\theta^*)} \quad (3.146)$$

Hence I can calculate the aggregate employment in the steady state, L^* .

$$L^* = N(1 - u^*) \quad (3.147)$$

²⁶In (3.144) both $h(n, z)$ and v_{tot} include x , the total measure of firms which is a function of e as shown in (3.13). However, the x terms cancel out so (3.144) is independent of e . Additionally, (3.145) is independent of e because $\Pi(n, z)$ is not a function of e . Entry can only affect the value of firms indirectly via θ . Controlling for θ and rU , (3.145) is independent of e .

Finally, while keeping $\theta = \theta^*$ and $rU = rU^*$, I search for such a value of e where the following holds:

$$L^* - L_{new} = L^* - \int_{z^*}^{\infty} \int_0^{n^*(z)} n h(n, z) dn dz = 0 \quad (3.148)$$

In (3.148) the only part that is a function of e is $h(n, z)$ because $h(n, z) = \frac{x g(n|z) f(z)}{1-F(z^*)} = \frac{e g(n|z) f(z)}{\delta}$. Thus I obtained θ^*, rU^* and e^* . As a result of finding e^* I have the correct joint distribution of firm size and productivity $h(n, z)$ and thus I can find all the aggregate endogenous objects such as total output, total wage bill or total vacancies²⁷.

3.5.3.2 Model with two-tier collective wage bargaining

In this version of the model the wage is given by:

$$w^C(n, z) = T + p(n, z) = (1 - \mu)b + (\mu - (1 - \epsilon)\omega) \frac{Y}{L} + (1 - \epsilon)\omega \frac{z}{n^{1-\alpha}}$$

The critical endogenous variables are: the labour market tightness θ , the tariff wage T and the level of firm entry e . All other endogenous objects of the model are just a function of these three variables and constant parameters.

First, I solve a system of 2 non-linear equations and 2 unknowns: θ and T . The following two equations are functions of θ and T only (not of e)²⁸.

²⁷These I could not calculate with only knowing θ^* and rU^* .

²⁸In (3.149) the only term that is a function of e is $h(n, z)$, but it is both in the numerator and in the denominator. Thus e terms cancel out and (3.149) is independent of e . Additionally, (3.150) is independent of e because $\Pi(n, z)$ is not a function of e . Entry can only affect the value of firms indirectly via θ . Controlling for θ and T , (3.150) is independent of e .

$$\begin{aligned}
T_{guess} - T_{new} &= 0 \\
T_{guess} - \left((1 - \mu)b + (\mu - (1 - \epsilon)\omega) \frac{Y}{L} \right) &= 0 \\
T_{guess} - (1 - \mu)b - (\mu - (1 - \epsilon)\omega) \frac{\int_{z^*}^{\infty} \int_0^{n^*(z)} y(n, z) h(n, z) dn dz}{\int_{z^*}^{\infty} \int_0^{n^*(z)} n h(n, z) dn dz} &= 0
\end{aligned} \tag{3.149}$$

$$\int_{z^*}^{\infty} \Pi(0, z) f(z) dz - F^e = 0 \tag{3.150}$$

I solve the above system of two non-linear equations using the following algorithm:

Algorithm 2 *Solving for θ and T :*

1. *Guess θ and T .*
2. *Apply value function iteration on (3.3) to solve for the value function $\Pi(n, z)$, the policy function $n'(n)$ and $v(n, z)$.*
3. *Calculate the firm target size $n^*(z)$ which is given by Lemma 6.*
4. *Solve for z^* using the Minimum Productivity Condition condition (3.12).*
5. *Given $v(n, z)$, θ , $n^*(z)$ and z^* , find the joint distribution of firm size and productivity $h(n, z)$ - steps in Appendix 3.5.3.4.*
6. *Check how close equations (3.149-3.150) are to zero. If sufficiently close, stop. We found θ^* and T^* . If not, go to Step 1 and update the guess of θ, T .*

Once I have found the equilibrium θ^* and T^* I solve for the level of firm entry, e in exactly the same way as in the case of individual wage bargaining. Thus I obtain θ^*, T^* and e^* and using these I solve for all endogenous objects of the model.

3.5.3.3 Model with complete centralisation of collective wage bargaining

Here I assume that $\epsilon = 1$, workers have zero local bargaining power. In that case $w^C = T$, we have complete centralisation, there is a single wage rate applying to all the firms in the industry and it is equal to the tariff wage T .

First, I solve a system of 2 non-linear equations and 2 unknowns: θ and T . The following two equations are functions of θ and T only (not of e)²⁹.

$$\begin{aligned}
T_{guess} - T_{new} &= 0 \\
T_{guess} - \left((1 - \mu)b + \mu \frac{Y}{L} \right) &= 0 \\
T_{guess} - (1 - \mu)b - \mu \frac{\int_{z^*}^{\infty} \int_0^{n^*(z)} y(n, z) h(n, z) dn dz}{\int_{z^*}^{\infty} \int_0^{n^*(z)} n h(n, z) dn dz} &= 0
\end{aligned} \tag{3.151}$$

$$\int_{z^*}^{\infty} \Pi(0, z) f(z) dz - F^e = 0 \tag{3.152}$$

I solve the above system of two non-linear equations using the following algorithm:

Algorithm 3 *Solving for θ and T :*

1. *Guess θ and T .*
2. *Apply value function iteration on (3.3) to solve for the value function $\Pi(n, z)$, the policy function $n'(n)$ and $v(n, z)$.*
3. *Calculate the firm target size $n^*(z)$ which is given by Lemma 6 where $(1 - \epsilon)\omega = 0$.*
4. *Solve for z^* using the Minimum Productivity Condition condition (3.12).*
5. *Given $v(n, z)$, θ , $n^*(z)$ and z^* , find the joint distribution of firm size and productivity $h(n, z)$ - steps in Appendix 3.5.3.4.*
6. *Check how close equations (3.151-3.152) are to zero. If sufficiently close, stop. We found θ^* and T^* . If not, go to Step 1 and update the guess of θ, T .*

Once I have found the equilibrium θ^* and T^* I solve for the level of firm entry, e in exactly the same way as in the case of individual wage bargaining. Thus I obtain θ^*, T^* and e^* and using these I solve for all endogenous objects of the model.

²⁹In (3.151) the only term that is a function of e is $h(n, z)$, but it is both in the numerator and in the denominator. Thus e terms cancel out and (3.151) is independent of e . Additionally, (3.152) is independent of e because $\Pi(n, z)$ is not a function of e . Entry can only affect the value of firms indirectly via θ . Controlling for θ and T , (3.152) is independent of e .

3.5.3.4 Calculating joint distribution of firm size and productivity

I calculate the joint distribution of firm size and productivity $h(n,z)$ in the following way. All firms start their life with no workers. All firms with the same time-invariant productivity z make the same discrete jumps in firm size as they grow towards their target size. Except that some of them die (with probability δ every period) and they differ in age. Still, firm growth is completely deterministic. Therefore I can calculate all the steps or "islands" that firms with a particular z will take.

Firm size "islands" for a given z :

$$\begin{aligned} n_{i+1} &= (1 - s)n_i + v(n_i, z)q(\theta) \quad \text{for } i = 1, 2, 3, \dots, \infty \\ n_0 &= 0 \end{aligned} \tag{3.153}$$

Mass of firms at every island m_i is given by the condition that every period inflow is equal to the outflow, thus the mass of firms jumping in size from the previous island must be equal to the mass of firms that leave this firm size island, either because of firm growth or due to firm death. In fact, outside of the target size, no firms remain at the same employment level for more than one period.

For island $n_0 = 0$ and certain z :

$$\underbrace{e f(z)}_{\text{inflow}} = \underbrace{\delta m_0}_{\text{outflow due to firm death}} + \underbrace{(1 - \delta)m_0}_{\text{due to firm growth}} \tag{3.154}$$

$$m_0 = e f(z)$$

For island n_1 and certain z :

$$\begin{aligned} e f(z)(1 - \delta) &= \delta m_1 + (1 - \delta)m_1 \\ m_1 &= e f(z)(1 - \delta) \end{aligned} \tag{3.155}$$

For island n_i and certain z :

$$m_i = e f(z)(1 - \delta)^i \quad (3.156)$$

We can see that the mass at each island is monotonically decreasing in the order i . The total mass of firms at islands up to n_j for a given z :

$$G(n_j) = \sum_{i=0}^j e f(z)(1 - \delta)^i \quad (3.157)$$

In the model firms initially grow very fast and then the growth slows down as they get closer to the target size $n^*(z)$. Thus initially firms are making big jumps, the firm size islands are far from each other. However, close to $n^*(z)$ the islands are closely clustered together. Firms only approach $n^*(z)$ in the limit. Hence the firm mass sequence is an infinite geometric series. We can find $G(n^*(z))$ using the formula for the sum of a geometric series³⁰.

$$\begin{aligned} G(n^*(z)) &= \sum_{i=0}^{\infty} e f(z)(1 - \delta)^i \\ &= e f(z) + e f(z)(1 - \delta) + e f(z)(1 - \delta)^2 + e f(z)(1 - \delta)^3 + \dots \\ &= \frac{e f(z)}{\delta} \end{aligned} \quad (3.158)$$

$G(n^*(z))$ gives the measure of all the firms that have time-invariant productivity equal to z (firms of all sizes). As a check, I can also find this sum in another way. The mass of firms with productivity z is equal to the share of firms that have productivity z , $\frac{f(z)}{1-F(z^*)}$, multiplied by the total mass of all firms, x that is given by (3.13).

$$\begin{aligned} G(n^*(z)) &= x \frac{f(z)}{1 - F(z^*)} \\ &= \frac{e f(z)}{\delta} \end{aligned} \quad (3.159)$$

Lets discuss how I use the results above to numerically calculate $h(n,z)$, the joint distri-

³⁰An infinite geometric series $A + AR + AR^2 + AR^3 + \dots$ where $|R| < 1$ has a sum given by $S = \frac{A}{1-R}$.

bution of firm size and productivity. I have a grid of values of z . For every z in the grid I calculate the firm size islands n_i using (3.153). I stop when $n_i - n_{i-1} < \zeta$ where $\zeta > 0$ arbitrarily small. I add the last element to each sequence which is $n^*(z)$, the target firm size for that z (defined by Lemma 3 for individual bargaining case and by Lemma 6 for the collective bargaining case). Next for each z in the grid I calculate the sequence of cumulative mass values $G(n_i)$ corresponding to every firm size island n_i using (3.157). I add the final element to each sequence, $G(n^*(z)) = \frac{e f(z)}{\delta}$ which is the mass of all firms for that value of z .

Using linear interpolation I convert the sequences above into continuous functions. Next I need to put all of them on the same grid of firm size n . For each value in the grid of firm size, I calculate the cumulative mass implied by the continuous function. I do this for every value of z . Thus I have a matrix where each column represents a different value of z in the firm productivity grid and each row represents a different value of n in the firm size grid. A value in the matrix for a particular (n, z) combination gives the cumulative mass of firms with productivity equal to z and firm size up to n .

I use numerical differentiation to convert this matrix of cumulative values into a matrix where each element gives the mass of firms for a particular (n, z) combination. Finally, I use linear approximation to convert this matrix into a function of two variables, n and z . Thus I obtain the joint distribution of firm size and productivity $h(n, z)$ which gives the mass of firms for each (n, z) combination.

Bibliography

- Abowd, J. and F. Kramarz (1999). *The analysis of labor markets using matched employer-employee data*. Handbook of Labor Economics, Volume 3, Volume 3B, Chapter 40. North Holland, Amsterdam.
- Abowd, J., F. Kramarz, and D. Margolis (1999). “High wages workers and high wages firms”. In: *Econometrica* 67, pp. 251–335.
- Acemoglu, D. and Autor (2011). *Skills, tasks and technologies: Implications for employment and earnings*. Handbook of labor economics, vol. 4, ed. David Card and Orley Ashenfelter. Amsterdam: Elsevier.
- Acemoglu, D. and W.B. Hawkins (2014). “Search with multi-worker firms”. In: *Theoretical Economics* 9(3), pp. 583–628.
- Alvarez, J., F. Benguria, N. Engbom, and Christian Moser (2018). “Firms and the Decline in Earnings Inequality in Brazil”. In: *American Economic Journal: Macroeconomics* 10(1), pp. 149–189.
- Andrews, M.J., L. Gill, T. Schank, and R. Upward (2008). “High Wage Workers and Low Wage Firms: Negative Assortative Matching or Limited Mobility Bias?” In: *Journal of the Royal Statistical Society* 171, pp. 673–697.
- Arai, M. (2003). “Wages, Profits, and Capital Intensity: Evidence from Matched Worker-Firm Data”. In: *Journal of Labor Economics* 21(3), pp. 593–618.
- Atkinson, A.B., T. Piketty, and E. Saez (2011). “Top Incomes in the Long Run of History”. In: *Journal of Economic Literature* 49(1), pp. 3–71.

- Autor, D. Dorn, L.F. Katz, C. Patterson, and J.V. Reenen (2020). “The Fall of the Labor Share and the Rise of Superstar Firms”. In: *Quarterly Journal of Economics* 135(2), pp. 645–709.
- Babina, T., W. Ma, C. Moser, and P.P. Ouimet and R. Zarutskie (2019). “Pay, Employment, and Dynamics of Young Firms”. In: *Opportunity and Inclusive Growth Institute Working Papers 21, Federal Reserve Bank of Minneapolis*.
- Barth, E., A. Bryson, J.C. Davis, and R.B. Freeman (2016). “It’s where you work: Increases in the dispersion of earnings across establishments and individuals in the United States”. In: *Journal of Labor Economics* 34, pp. 67–97.
- Barth, E. and K.O. Moene (2013). “Why do Small Economies have such Small Wage Differentials?” In: *Nordic Economic Policy Review* 1, pp. 139–170.
- Barth, E., K.O. Moene, and F. Willumsen (2014). “The Scandinavian model - an interpretation”. In: *Journal of Public Economics* 117, pp. 60–72.
- Bauer, C. and J. Lingens (2013). “Does Collective Wage Bargaining Restore Efficiency in a Search Model with Large Firms?” In: *The Economic Journal*, 124, pp. 1066–1085.
- Becker, G. (1973). “A Theory of Marriage: Part I”. In: *Journal of Political Economy* 81, pp. 813–846.
- Benito, A. (2000). “Inter-industry wage differentials in Great Britain”. In: *Oxford Bulletin of Economics and Statistics* 62, pp. 727–746.
- Blatter, M., S. Muehlemann, and S. Schenker (2012). “The costs of hiring skilled workers”. In: *European Economic Review* 56, pp. 20–35.
- Bloom, N., F. Guvenen, B.S. Smith, J. Song, and T. von Wachter (2018). “The Disappearing Large-Firm Wage Premium”. In: *AEA Papers and Proceedings* 108, pp. 317–322.
- Boeri, T. and M.C. Burda (2009). “Preferences for collective versus individualised wage setting”. In: *The Economic Journal* 119, pp. 1440–1463.
- Boeri, T., A. Ichino, E. Moretti, and J. Posch (2019). “Wage Equalization and Regional Misallocation: Evidence from Italian and German Provinces”. In: *IZA Working Paper*.

- Bonhomme, S., T. Lamadon, and E. Manresa (2019). “A Distributional Framework for Matched Employer Employee Data”. In: *Econometrica* 87(3), pp. 699–739.
- Braun, S. (2011). “Unionisation structures, productivity and firm performance: New insights from a heterogeneous firm model”. In: *Labour Economics* 18, pp. 120–129.
- Cahuc, P. and E. Wasmer (2001). “Does Intra-firm Bargaining Matter in the Large Firm’s Matching Model?” In: *Macroeconomic Dynamics* 5(5), pp. 742–747.
- Caju, P., A. Lamo, S. Poelhekke, G. Katay, and D. Nicolitsas (2010). “Inter-industry wage differentials in EU countries: what do cross-country time varying data add to the picture?” In: *Journal of the European Economic Association* 8(2-3), pp. 478–486.
- Caju, P., F. Rycx, and I. Tojerow (2011). “Inter-industry Wage Differentials: How Much Does Rent Sharing Matter?” In: *The Manchester School* 79(4), pp. 691–717.
- Calmfors, L. (2001). *The Future of Collective Bargaining in Europe*. Tito Boeri, Agar Brugiavini and Lars Calmfors, (red) *The Role of Unions in the Twenty-First Century*. Oxford University Press: Oxford.
- Calmfors, L. and J. Driffil (1988). “Bargaining structure, corporatism, and macroeconomic performance”. In: *Economic Policy* 6, pp. 13–61.
- Card, D., A.R. Cardoso, J. Heining, and P. Kline (2018). “Firms and Labor Market Inequality: Evidence and Some Theory”. In: *Journal of Labor Economics* 36(S1), pp. 13–70.
- Card, D., J. Heining, and P. Kline (2013). “Workplace heterogeneity and the rise of West German wage inequality”. In: *The Quarterly Journal of Economics* 128, pp. 967–1015.
- Casado-Diaz, J.M. and H. Simon (2008). “Industry wage premia and collective bargaining revisited: evidence from Spain”. In: *Applied Economics Letters* 15, pp. 477–481.
- Cooper, R., J Haltiwanger, and J.L. Willis (2004). “Dynamics of Labor Demand: Evidence from Plant-Level Observations and Aggregate Implications”. In: *National Bureau of Economic Research (NBER) Working Paper 1029*.

- Davis, S.J., J.C. Haltiwanger, and S. Schuh (1996). *Job Creation and Destruction*. MIT Press, Cambridge, Massachusetts.
- Devicienti, F., B. Fanfani, and A. Maida (2019). “Collective Bargaining and the Evolution of Wage Inequality in Italy”. In: *British Journal of Industrial Relations* 57(2), pp. 377–407.
- Dickens, W.T. (1987). “Inter-industry wage differences and theories of wage determination”. In: *NBER Working Paper No. 2271*.
- Due, J., J.S. Madsen, C.S. Jensen, and L.K. Petersen (1994). *The Survival of the Danish Model*. DJOF Pub.
- Edin, P.A. and J. Zetterberg (1992). “Inter-industry wage differentials: Evidence from Sweden and a comparison with the United States”. In: *American Economic Review* 82, pp. 1341–1349.
- Elsby, M.W.L. and R. Michaels (2013). “Marginal Jobs, Heterogeneous Firms, and Unemployment Flows”. In: *American Economic Journal: Macroeconomics* 5(1), pp. 1–48.
- Faggio, G., K.G. Salvanes, and J. Van Reenen (2010). “The evolution of inequality in productivity and wages: panel data evidence”. In: *Industrial and Corporate Change* 19(6), pp. 1919–1951.
- Fanfani, B. (2019). “The Employment Effects of Collective Bargaining”. In: *Working paper 064, Department of Economics and Statistics, University of Torino*.
- Felbermayr, G. and J. Prat (2011). “Product Market Regulation, Firm Selection and Unemployment”. In: *Journal of the European Economic Association* 9(2), pp. 278–317.
- Felbermayr, G., J. Prat, and H. Schmerer (2011). “Globalization and labor market outcomes: Wage bargaining, search frictions, and firm heterogeneity”. In: *Journal of Economic Theory* 146, pp. 39–73.
- Fields, G. S. (2003). “Accounting for Income Inequality and its Change: A New Method, With Application to the Distribution of Earnings in the United States”. In: *Research in labor economics* 22.

- Fiorio, C. and S. Jenkins (2010). “INEQRBD: Stata module to calculate regression-based inequality decomposition”. In:
- Gannon, B. and B. Nolan (2004). “Inter-industry wage differentials in Ireland”. In: *Economic and Social Review* 35, pp. 157–182.
- Gannon, B., R. Plasman, F. Rycx, and I. Tojerow (2007). “Inter-industry wage differentials and the gender wage gap: Evidence from European countries”. In: *Economic and Social Review* 38, pp. 135–155.
- Gibbons, R. and Katz (1992). “Does Unmeasured Ability Explain Inter-Industry Wage Differentials”. In: *The Review of Economic Studies* 59(3), pp. 515–535.
- Gittleman, M. and E. Wolff (1993). “International comparisons of inter-industry wage differentials”. In: *Review of Income and Wealth* 39, pp. 295–312.
- Goux, D. and E. Maurin (1999). “Persistence of interindustry wage differentials: A re-examination using matched worker-firm panel data”. In: *Journal of Labor Economics* 17, pp. 516–521.
- Hall, R.E. and P.R. Milgrom (2008). “The limited influence of unemployment on the wage bargain”. In: *American Economic Review* 98(4), pp. 1653–1674.
- Hartog, J., R. Van Opstal, and C. Teulings (1997). “Inter-industry wage differentials and tenure effects in the Netherlands and the U.S”. In: *De Economist* 145, pp. 91–99.
- Hartog, J., P. Pereira, and J. Vieira (2000). “Inter-industry wage dispersion in Portugal”. In: *Empirica* 27, pp. 353–364.
- Hopenhayn, H.A. (1992). “Entry, Exit, and firm Dynamics in Long Run Equilibrium”. In: *Econometrica* 60(5), pp. 1127–1150.
- Ibsen, C.L. (2015). “Three approaches to coordinated bargaining: A case for power-based explanations”. In: *European Journal of Industrial Relations* 21(1), pp. 39–56.
- Ibsen, C.L. (2016). “The Role of Mediation Institutions in Sweden and Denmark after Centralized Bargaining”. In: *British Journal of Industrial Relations* 54(2), pp. 285–310.

- Jimeno, J.F. and C. Thomas (2013). “Collective bargaining, firm heterogeneity and unemployment”. In: *European Economic Review* 59, pp. 63–79.
- Johnston, A., B. Hancke, and S. Pant (2014). “Comparative institutional advantage in the European sovereign debt crisis”. In: *Comparative Political Studies* 47, pp. 1771–1800.
- Kahn, L. (1998). “Collective bargaining and the interindustry wage structure: International evidence”. In: *Economica* 65, pp. 507–534.
- Katz and Autor (1999). *Changes in the wage structure and earnings inequality*. Handbook of labor economics, vol. 3, ed. Orley Ashenfelter and David Card. Amsterdam: Elsevier.
- Katz and L.H. Summers (1989). “Industry rents: Evidence and implications”. In: *Brookings Papers on Economic Activity: Microeconomics*, pp. 209–290.
- Kline, P., R. Saggio, and M. Sølvssten (2019). “Leave-out estimation of variance components”. In: *Working paper*.
- Krueger, A.B. and L.H. Summers (1988). “Efficiency Wages and the Inter-Industry Wage Structure”. In: *Econometrica* 56(2), pp. 259–293.
- Lamadon, T., M. Mogstad, and B. Setzler (2019). “Imperfect Competition, Compensating Differentials and Rent Sharing in the U.S. Labor Market”. In: *NBER Working Paper No. w25954*.
- Magda, I., F. Rycx, I. Tojerow, and D. Valsamis (2011). “Wage differentials across sectors in Europe: An east-west comparison”. In: *Economics of Transition* 19(4), pp. 749–769.
- Manacorda, M. (2004). “Can the Scala Mobile Explain the Fall and Rise of Earnings Inequality in Italy? A Semiparametric Analysis, 1977–1993”. In: *Journal of Labor Economics* 22(3), pp. 585–613.
- Manning, A. (2006). “A Generalised Model of Monopsony”. In: *The Economic Journal* 116, pp. 84–100.
- Martins, P.S. (2004). “Industry wage premia: evidence from the wage distribution”. In: *Economics Letter* 83, pp. 157–163.

- Melitz, M. (2003). “The Impact of Trade on Intraindustry Reallocations and Aggregate Industry Productivity”. In: *Econometrica* 71, pp. 1695–1725.
- Mincer, J. (1974). “Schooling, Experience and Earnings”. In: *National Bureau of Economic Research*.
- Moene, K.O. (1988). “Union’s Threats and Wage Determination”. In: *The Economic Journal* 98, pp. 471–483.
- Moene, K.O. and M. Wallerstein (1997). “Pay Inequality”. In: *Journal of Labor Economics* 15(3), pp. 403–430.
- Moene, K.O., M. Wallerstein, and M. Hoel (1993). *Part II: bargaining structure and economic performance*. Flanagan, R.J., Moene, K.O., Wallerstein, M. (Eds.), Trade Union Behaviour, Pay Bargaining and Economic Performance. Clarendon Press, Oxford.
- Murphy, K.M. and R.H. Topel (1987). *Unemployment, Risk and Earnings*. Unemployment and the Structure of Labor Markets. Oxford: Basil Blackwell.
- Nergaard, K. (2014). “Trade Unions in Norway: Coordinated Wage Bargaining and Workplace Level Co-determination”. In: *Friedrich-Ebert-Stiftung Working Paper*.
- OECD (2001). *Businesses’ Views on Red Tape: Administrative and Regulatory Burdens on Small and Medium-sized Enterprises*. OECD Publishing.
- OECD (2019). *Negotiating Our Way Up: Collective Bargaining in a Changing World or Work*. OECD Publishing, Paris.
- Ortigueira, S. (2013). “The Rise and Fall of Centralized Wage Bargaining”. In: *Scandinavian Journal of Economics* 115, pp. 825–855.
- Pinto, M. (2017). “The Impact of Unionization Structures with Heterogeneous Firms and Rent-Sharing Motives”. In: *The Scandinavian Journal of Economics* 121(1), pp. 298–325.
- Rehn, G. (1952). *The problem of stability: an analysis of some policy proposals*. Turvey, R. (Ed.), Wages policy under full employment. W. Hodge, London.

- Rusinek, M. and F. Rycx (2013). “Rent-Sharing Under Different Bargaining Regimes: Evidence from Linked Employer-Employee Data”. In: *British Journal of Industrial Relations* 51, pp. 28–58.
- Rycx, F. (2002). “Inter-Industry Wage Differentials: Evidence from Belgium in a Cross-National Perspective”. In: *De Economist* 150(5), pp. 555–568.
- Schmieder, J.F. (2013). “What Causes Wage Dispersion? Evidence from New Firms”. In: *Working Paper*.
- Shimer, R. (2005). “The Cyclical Behavior of Equilibrium Unemployment and Vacancies”. In: *American Economic Review* 95(1), pp. 25–49.
- Shimer, R. and L. Smith (2000). “Assortative Matching and Search”. In: *Econometrica* 68, pp. 343–370.
- Silva, J.I. and M. Toledo (2009). “Labor Turnover Costs and the Cyclical Behavior of Vacancies and Unemployment”. In: *Macroeconomic Dynamics* 13(1), pp. 76–96.
- Slichter, S.H. (1950). “Notes on the structure of wages”. In: *Review of Economics and Statistics* 32(1), pp. 80–91.
- Smith, E. (1999). “Search, Concave Production and Optimal Firm Size”. In: *Review of Economic Dynamics* 2(2), pp. 456–471.
- Song, J., D.J. Price, F. Guvenen, N. Bloom, and T. von Wachter (2019). “Firming Up Inequality”. In: *The Quarterly Journal of Economics* 134, pp. 1–50.
- Sorkin, I. (2018). “Ranking Firms using Revealed Preference”. In: *The Quarterly Journal of Economics* 133, pp. 1331–1393.
- Stole, L.A. and J. Zwiebel (1996). “Intra-firm bargaining under non-binding contracts”. In: *Review of Economic Studies* 63, pp. 375–410.
- Swenson, P.A. (1991). “Bringing capital back in, or social democracy reconsidered: Employer power, cross-class alliances, and centralization of industrial relations in Denmark and Sweden”. In: *World Politics* 43(4), pp. 513–544.

- Syversen, C. (2011). “What Determines Productivity?” In: *Journal of Economic Literature* 49(2), pp. 326–365.
- Teulings, C. and J. Hartog (1998). *Corporatism or competition? Labour Contracts, Institutions and Wage Structures in International Comparison*. Cambridge University Press.
- Thaler, R. (1989). “Anomalies: Interindustry wage differentials”. In: *Journal of Economic Perspectives* 3, pp. 181–193.
- Traxler, F., B. Brandl, and V. Glassner (2008). “Pattern bargaining: an investigation into its agency, context and evidence”. In: *British Journal of Industrial Relations* 46, pp. 33–58.
- Vainiomaki, J. and S. Laaksonen (1995). “Interindustry wage differentials in Finland: Evidence from longitudinal census data for 1975 to 1985”. In: *Labour Economics* 2, pp. 161–173.
- Visser, J. (2016). “ICTWSS: Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts in 55 countries between 1960 and 2018”. In: *Amsterdam Institute for Advanced Labour Studies AIAS*.
- Vona, F. and L. Zamparelli (2014). “Centralized Wage Setting and Active Labor Market Policies in Frictional Labor Markets: The Nordic Case”. In: *Eastern Economic Journal* 40, pp. 349–364.
- Zweimuller, J. and E. Barth (1994). “Bargaining Structure, Wage Determination, and Wage Dispersion in 6 OECD Countries”. In: *KYKLOS* 47, pp. 81–93.